# Improved IPM Systems in the Australian Sweet Corn Industry

Peter Deuter
QLD Department of Primary Industries & Fisheries

Project Number: VG05035

**VG05035**

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# Improved IPM Systems in the Australian Sweet Corn Industry

# Final Report

**HAL Project Number :-** VG05035 (31/12/2008)

**Project Title :-** Improved IPM Systems in the Australian Sweet Corn Industry

**Author :-** Peter Deuter

**Research Provider :-** Department of Primary Industries and Fisheries, Queensland.

## Contents

## HAL Project Number :- VG05035

## Project Leader :-

Peter Deuter, Senior Principal Horticulturist; DPI&F, Queensland, Locked Bag 7, M/S 437, Gatton Research Station, Gatton, Qld, 4343; (07) 5466 2233; (0407) 636907; peter.deuter@dpi.qld.gov.au

## Key Personnel :-

Tony Napier - District Horticulturist; NSW Department of Primary Industries
John Duff - Senior Plant Protectionist; DPI&F, Queensland
Austin McLennan - Entomologist; formerly DPI&F, Qld
Dr Sandra McDougall - Technical Specialist (Vegetables); NSW Department of Primary Industries
Dr Siva Subramaniam - Senior Entomologist; DPI&F, Queensland
Andrew Watson - Research Officer; NSW Department of Primary Industries
Ross Wright - Senior Horticulturist; formerly DPI&F, Queensland
Leigh James - District Horticulturist; NSW Department of Primary Industries
Jerry Lovatt - Senior Information Extension Horticulturist; DPI&F, Queensland
Dr Sonya Broughton - Entomologist; Department of Agriculture and Food, Western Australia
Dr Gerry MacManus - Plant Pathologist; DPI&F, Queensland
Dr Lara Senior - Entomologist; DPI&F, Queensland

## Purpose of this report :-

Report on our understanding of the management of a broader range of pests (including helicoverpa) and diseases in an IPM context.

## Funding sources (levy and non-levy) :-

Horticulture Australia Ltd; Department of Primary Industries & Fisheries, Qld; Department of Primary Industries, NSW; Department of Agriculture and Food, WA; Bayer CropScience; Dupont Agricultural Products; Sumitomo Chemical Australia.

## Collaborating institutions :- NSWDPI, DAWA

## Date :- 27/2/2009

## Disclaimer:

# 1.00 Media Summary

## Key components of the project

The work program included :- An assessment of new "soft options" as additional components of Integrated Pest Management (IPM); Identifying naturally occurring beneficial organisms (natural enemies) which have the potential to contribute to sweet corn IPM systems; Conducting a Disease Survey of the Industry; and Developing and testing improved IPM strategies, which included new "soft options" and the enhancement of naturally occurring beneficials.

## Industry significance of the project

The need to manage 'secondary' pests and diseases, whilst maintaining and/or improving the management of helicoverpa, was identified by the sweet corn industry in May 2001 (at the completion of VG97036). Subsequently the IPM project, "Improved IPM Systems in the Australian Sweet Corn Industry" – VG05025 was funded to build on these outcomes and to further understand the complexity of IPM in sweet corn, by focussing on the broader range of insect pests and their management in an IPM context.

## Key outcomes

The R&D work program has demonstrated that four (4) additional 'soft options' insecticides and one (1) miticide have potential, and registration should continue to be pursued on behalf of the Australian sweet corn industry. These are Movento™ and SCSI-03 (no trade name), which are effective against sucking insects (thrips and aphids); Belt™ and Coragen™, which are very effective against helicoverpa and Sorghum Head Caterpillar; and Paramite™, which suppresses 2-spotted mite populations. These new insecticides and miticide appear to have low impacts on beneficial arthropods and potentially have a very good "IPM Fit".

Naturally occurring beneficials (natural enemies) continue to have important regulatory impacts on helicoverpa, aphids and mites, especially in tropical and sub-tropical production systems. It is expected that natural enemies are likely to be more prevalent and therefore more effective, when these additional `softer' insecticides are available and incorporated into IPM systems.

The impact from disease infestations on sweet corn production is quite low, a reflection on how well variety selection has been adopted by growers in implementing their IPM systems. It also reflects how well breeding programs have been able to incorporate resistance to several diseases common in Australia which, particularly in the temperate areas of the country, all but remove the necessity to apply fungicides. It also reflects the fact that all production districts have been affected by varying levels of drought for many years.

## Recommendations for future R&D

- Registration should continue to be pursued on behalf of the Australian sweet corn industry, for four (4) sucking pests and lepidopteran 'soft options' insecticides, Movento™, SCSI-03, Belt™ and Coragen™ one (1) miticide, Paramite™. These new insecticides and miticide have shown to have potential as components of a sweet corn IPM system.

- Appropriate guidelines for managing insecticide resistance in sweet corn pests should be implemented at regional level, when registration of these soft options occurs.

- Additional investigations are required to determine the impacts of these additional sucking pests and lepidopteran "soft options" (Movento™, SCSI-03, Belt™ and Coragen™) on beneficial arthropods. Assessments in this project indicate a low to moderate impact on some beneficials, and no impact on trichogramma.

- Determine the contribution of naturally occurring beneficial arthropods including brown and green lacewings, ladybirds, spiders and damsel bugs, which occur regularly in sweet corn fields. Project results indicate that their contribution to the biological control of helicoverpa and sucking pests is important, but quite variable from season to season and field to field.
- Document the benefits and costs, including the barriers to implementation of IPM, most particularly in temperate production regions, as pest management (including helicoverpa management) is still an issue for the industry. There are additional control options available as a result of the IPM projects funded over the past 10 years, but there is only a limited application of the outcomes of this IPM R&D in temperate production regions (in contrast to tropical and sub-tropical regions of Australia). In the processing industry, this is because the costs and applicability of IPM components, particularly the 'soft options', are considered too expensive or inappropriate to be considered a part of the standard pest management system.
- Near Infra-red Technologies for inline scanning for damaged cobs is a proven technology worth commercialising to reduce the high labour costs in the packing shed for checking sweet corn cobs for end fill and damage prior to packing.

## Recommendations for practical application to industry

- Subject to the registration of all or some of the four sucking pests and lepidopteran 'soft options' insecticides, which have shown to have potential, incorporation of these as components of a sweet corn IPM system is recommended.
- For the processing sweet corn industry in southern Australia, where broad spectrum insecticides are used in rotation with Success™, it is recommended that higher water rates be applied by a boom fitted with droppers. This method gave significantly better results than applying the insecticides at lower water rates with no droppers fitted; and at silking, rotating the 'soft option' Coragen™ with Success™ is recommended, as it provides significantly greater helicoverpa control, and will reduce the resistance pressure on both insecticides.
- The protection of naturally occurring beneficials has been shown to be an essential component of sweet corn integrated pest management. The use of soft options insecticides where possible is recommended to enhance the effects of these naturally occurring beneficials.
- Monitoring of pests and beneficials for decision making purposes is an essential component of sweet corn integrated pest management. Continued monitoring is recommended to enable the use of soft options and the reduction in the use of broad spectrum insecticides.
- Variety breeding and selection programs need to continue to maintain and improve on the current level of disease resistance. This is necessary to enable the industry to maintain its current low level of dependence on the application of fungicides, and is particularly important in face of the low incidence of diseases generally, as all production districts have been affected by varying levels of drought for many years.

## Disclaimer:

***A range of insecticides are referred to in this report. Where an insecticide is named together with ™ as a superscript, this refers to the insecticides' Registered Trade Name. This DOES NOT imply that this insecticide is registered for use on sweet corn in Australia. It is important that the registration status of all insecticides are verified prior to their application to sweet corn in Australia.***

# 2.00 Technical Summary

## Nature of the problem

The need to manage 'secondary' pests and diseases, whilst maintaining and/or improving the management of helicoverpa, was identified by the sweet corn industry in May 2001 (at the completion of VG97036).

Subsequently the IPM project, “Improved IPM Systems in the Australian Sweet Corn Industry” – VG05025 was funded to build on the outcomes of VG97036 and to further understand the complexity of IPM in sweet corn, by focussing on the broader range of pests and diseases, and their management in an IPM context.

Some of these secondary pests of sweet corn have yield reducing effects, and others are contaminants in product destined for both domestic and export markets. The effects are product rejection (an export and domestic market access issue), downgrading and/or reduced $ returns, and reduced marketable yields.

## Description of the science undertaken

The work program included :- An assessment of new “soft options” as additional components of Integrated Pest Management; Identifying naturally occurring beneficial organisms (natural enemies) which have the potential to contribute to sweet corn IPM systems; Conducting a Disease Survey of the Industry; and Developing and testing improved IPM strategies, which included new “soft options” and the enhancement of naturally occurring beneficials.

## Major research findings and industry outcomes

The R&D work program has demonstrated that four (4) additional ‘soft options’ insecticides have potential, and registration should continue to be pursued on behalf of the Australian sweet corn industry. These soft options are :-

- Two (2) new sap sucking pests ‘soft options’, Movento™ and SCSI-03b (no trade name allocated) were effective against sucking insects (thrips and aphids) and one (1) miticide, Paramite™, has suppressed 2-spotted and red spider mite populations. These new insecticides and miticide do appear to have minimal impact on beneficial arthropods, although they do not appear to affect trichogramma populations and potentially have a very good “IPM Fit”.
- Belt ™ and Coragen ™ are very effective against helicoverpa and Sorghum Head Caterpillar, and appear to have low impact on beneficial insects.
- In laboratory and semi-field trails, Movento ™ had nil or a minor impact on the beneficials tested; Belt ™ and Coragen ™ varied from a moderate to nil impact; and trichogramma was not impacted by any of these three ‘soft options’.

Naturally occurring beneficials (natural enemies) continue to have an important regulatory impact on helicoverpa, aphids and mites, especially in tropical and sub-tropical production systems. It is expected that natural enemies are likely to be more prevalent and therefore more effective, when the `softer’ insecticides are available and incorporated into IPM systems.

The impact from disease infestations on sweet corn production is quite low, a reflection on how well variety selection has been adopted by growers in implementing their IPM systems. It also reflects how well breeding programs have been able to incorporate resistance to several diseases common in Australia which, particularly in the temperate areas of the country all but remove the necessity to apply fungicides. It also reflects the fact that all production districts have been affected by varying levels of drought for many years.

## Recommendations to industry, research peers and HAL

- Registration should continue to be pursued on behalf of the Australian sweet corn industry, for four (4) sucking pests and lepidopteran 'soft options' insecticides, Movento™, SCSI-03, Belt™ and Coragen™ ; and one (1) miticide, Paramite™, which has suppressed the 2-spotted and red spider mite populations and demonstrated as a potential candidate for mites control in sweet corn. The five (5) soft options have potential as components of a sweet corn IPM system.
- Appropriate guidelines for managing insecticide resistance in sweet corn pests should be implemented at regional level, when registration of these soft options occurs.
- Additional investigations are required to determine the impacts of the "soft options" (Movento™, SCSI-03, Belt ™ Coragen ™ and Paramite™) on beneficial arthropods. Assessments in this project indicate a moderate to low impact on some beneficials, and no impact on trichogramma.
- Determine the contribution of naturally occurring beneficial arthropods including brown and green lacewings, ladybirds, spiders and damsel bugs, which occur regularly in sweet corn fields. Project results indicate that their contribution to the biological control of helicoverpa and sucking pests is important, but quite variable from season to season and field to field.
- For the processing sweet corn industry in southern Australia, where broad spectrum insecticides are used in rotation with Success™, it is recommended that higher water rates be applied by a boom fitted with droppers, as this treatment gave significantly better results than applying the insecticides at lower water rates with no droppers fitted; and at silking, rotating the 'soft option' Coragen ™ with Success™ is recommended, as it provides significantly greater helicoverpa control, and will reduce the resistance pressure on both insecticides.
- For the Australian sweet corn industry :-
    - The protection of naturally occurring beneficials has been shown to be an essential component of sweet corn integrated pest management. This is particularly the case in tropical and sub-tropical production districts, where pest pressures are much higher, and the benefits of beneficials in particular seasons are very high. In temperate production districts, where pest pressures are often not as high, and beneficials numbers are low and sometimes absent, the benefits have been shown, although not as high as in northern regions.
    - Monitoring of pests and beneficials for decision making purposes is an essential component of sweet corn integrated pest management. This is especially the case for those IPM systems which have heavily utilised soft options and reduced the use of broad spectrum insecticides.
    - Document the benefits and costs, including the barriers to implementation of IPM, most particularly in temperate production regions, as pest management (including helicoverpa) is still an issue for the industry. There are additional control options available as a result of the IPM projects funded over the past 10 years, but there is only a limited application of the outcomes of this IPM R&D in temperate production regions (in contrast to tropical and sub-tropical regions of Australia). In the processing industry, this is because the costs and applicability of IPM components, particularly the 'soft options', are considered too expensive or inappropriate to be included as a part of the standard pest management system.
    - Variety breeding and selection programs need to continue to maintain and improve on the current level of disease resistance. This is necessary to enable the industry to maintain its current low level of dependence on the application of fungicides, and is particularly

important in face of the low incidence of diseases generally, as all production districts have been affected by varying levels of drought for many years.

- It is recommended that the sweet corn industry consider the following issues for further R&D investment :-
    - Increase sweet corn productivity and profitability through increased yields per unit of input and per plant.
    - Near Infra-red Technologies for inline scanning for damaged cobs is a proven technology worth commercialising to reduce the high labour costs in the packing shed for checking sweet corn cobs for end fill and damage prior to packing.
    - The costs and the barriers to the implementation of IPM need to be documented, most particularly in southern production regions, as pest management (including helicoverpa) is still an issue for the industry. Investigate the cause and solutions to poor 'end fill' – this is a production issue associated with some susceptible cultivars and environment (high temperature and low humidity at silking) and pest management, and will be exacerbated by future climate change.
    - Investigate the health benefits of sweet corn to increase consumption of sweet corn as a functional food.
    - Increase the domestic market for white and bicolour sweet corn which will lead to increased export opportunities.
    - Prepare for climate change by developing adaptation strategies and understanding impacts of climate change and climate variability on the sweet corn industry.
    - Build and maintain soil health through research and extension activities.

## Contribution to new technology

Four (4) sucking pests and lepidopteran 'soft options' insecticides, Movento ™, SCSI-03, Belt ™ and Coragen ™, and one (1) miticide, Paramite™, have potential, and registration should continue to be pursued on behalf of the Australian sweet corn industry.

## Recommendation for future work

- Determine the impacts of these additional sucking pests, lepidopteran and mite "soft options" (Movento ™, SCSI-03, Belt ™, Coragen ™ and Paramite ™) on beneficial arthropods. Assessments in this project indicate a moderate to low impact on some beneficials, and no impact on trichogramma.
- Document the benefits and costs, including the barriers to implementation of IPM, most particularly in temperate production regions, as pest management (including helicoverpa) is still an issue for the industry. There are additional control options available as a result of the IPM projects funded over the past 10 years, but there is only a limited application of the outcomes of this IPM R&D in temperate production regions (in contrast to tropical and sub-tropical regions of Australia). In the processing industry, this is because the costs of IPM components, particularly the 'soft options', are considered too expensive or inappropriate to be included as a part of the standard pest management system.
- Registration should continue to be pursued on behalf of the Australian sweet corn industry, for four (4) sucking pests and lepidopteran 'soft options' insecticides, Movento ™, SCSI-03, Belt ™ and Coragen ™, and one (1) miticide, Paramite™, which have shown to have potential.

- Develop appropriate insecticide resistance guidelines and implement at regional level, when registration of these soft options occurs.
- Near Infra-red Technologies for inline scanning for damaged cobs is a proven technology. The step to commercialising to reduce the high labour costs in the packing shed for checking sweet corn cobs for end fill and damage prior to packing' has not be followed through.

## Disclaimer:

***A range of insecticides are referred to in this report. Where an insecticide is named together with ™ as a superscript, this refers to the insecticides' Registered Trade Name. This DOES NOT imply that this insecticide is registered for use on sweet corn in Australia. It is important that the registration status of all insecticides are verified prior to their application to sweet corn in Australia.***

# 3.00 Introduction (including review of literature)

## 3.10 Historical Background.

In 1995, the Australian Sweet Corn industry produced 73 000 t for an on-farm value of $30.5M. Sweet corn has continued to be grown in all states of Australia with the majority being produced in Queensland (Qld), New South Wales (NSW) and Victoria. In 1995, Qld produced 19% of the Australian tonnage and 36% of the $ value (14 000 t and $11M annually); NSW produced 53% of the Australian tonnage from 2200 ha, mostly for the processed market. Victoria produced 10% of the Australian tonnage for fresh domestic and export markets.

Fresh in-husk sweet corn was regularly exported in the early 1990's, but market access was made difficult because of difficulties in managing helicoverpa (*Helicoverpa armigera*). Insect pests are no longer the major difficulty they were for exporters, but the profitability of export markets is preventing most growers from attempting to supply. This in part has been due to the value of the $A.

Currently, sweet corn is grown in all states of Australia (but mainly Qld and NSW), by 210 growers on 5900ha, producing 62,575t (ABS, 2008). Fresh market production extends across all months of the year, ensuring a continuity of supply to Australian domestic consumers every day of the year. Processing production is more concentrated to allow for throughput at factory. The industry is estimated to be worth in excess of $70M (although the latest ABS has it at $49M).

Fresh market expansion is occurring, as sweet corn is one of a few vegetable crops which is increasing in domestic consumption. Over the last five years, there has been particularly strong growth in sweet corn with an annual growth rate in excess of 19%. Marketing has also changed over the years for fresh sweet corn. There has been a move away from whole loose cobs to much of the fresh sweet corn produced being trimmed and marketed in tray packs. This has increased the value of the product and reduced the impact of helicoverpa damage. However there has been increased interest in marketing of whole cobs. The major fresh market in Australia is for yellow sweet corn with only small market segments for the bicolour or white sweet corn.

Even though there has been a recent decline in the processing sector, sweet corn has essentially maintained its importance amongst the large range of crops grown in Australia, and is likely to do so for the foreseeable future. Frozen vegetable imports increased significantly in 2007/08, and frozen sweet corn imports more than doubled from $13M to $29M in the 12 months to June 2008 (AusVeg, 2008).

Helicoverpa (*Helicoverpa armigera*) has always been the major pest of sweet corn, and until the early 1990's it was easily controlled by scheduled sprays of carbamates, organo-phosphates or synthetic pyrethroids. By 1994, growers in Queensland, NSW and Victoria were having difficulties supplying a fresh product to the export market in South East Asia. These growers had significant difficulties due to the inability to produce cobs free from helicoverpa larvae and larval damage. This was due to the high levels of insecticide resistance which occurs in *Helicoverpa armigera* (helicoverpa).

Pyrethroid insecticide resistance was 57% and 41% respectively in two samples submitted from the Lockyer Valley (Queensland) in Dec/Jan 1995/96, and carbamate resistance was 15% in Jan 1996. Unmanageable levels of resistance were recorded in North Queensland in the winter of 1996. These levels represented the magnitude of the problem in all production districts in Australia, and were continuing to rise towards unmanageable levels.

The range of synthetic insecticides registered on sweet corn was small, and increasing resistance levels were making them less effective. In the case of the registered carbamate insecticides, resistance levels had been assessed at or near 100% in North Queensland in the winter of 1996. Complete crop failure occurred in these situations.

## 3.20 Current Situation.

Fresh in-husk sweet corn was regularly exported in the early 1990's, but market access was curtailed because of difficulties in managing helicoverpa. Insect pests are no longer the major difficulty they were for exporters in the 1990's, but the profitability of the export markets is preventing most growers from attempting to supply. This in part has been due to the value of the $A.

Fresh market expansion is occurring as sweet corn is one of a few vegetable crops which is increasing in domestic consumption. Over the last five years, there has been particularly strong growth in sweet corn with an annual growth rate in excess of 19%. Marketing has also changed over the years for fresh sweet corn. There has been a move away from whole loose cobs to much of the fresh sweet corn produced being trimmed and marketed in tray packs. This has increased the value of the product and reduced the impact which helicoverpa damage has on whole cobs. However recently there has been some increased interest in marketing of whole cobs.

Frozen vegetable imports increased significantly in 2007/08, and frozen sweet corn imports more than doubled from $13M to $29M in the 12 months to June 2008.

Helicoverpa remains the major insect pest of sweet corn in the Riverina region of NSW, with the range of sucking pests (including aphids and thrips) only considered as a minor secondary problem. The sweet corn industry in the Riverina has not adopted 'soft options' for the management of helicoverpa. Two to three applications of broad spectrum insecticides are commonly used as the primary management tool which generally starts at early tasselling, by sweet corn growers who are producing sweet corn for the processing market.

In Western Australia (WA) sweet corn is grown commercially in two main areas: to the north in Broome and Carnarvon, and in the south around Perth. Around Perth, sweet corn is grown from November-April in Wanneroo, north of Perth, and at Baldivis, south of the Perth metropolitan area. Up to 20-30 plantings of sweet corn can be grown during the southern growing period.

Helicoverpa is regarded to be the primary pest of sweet corn in Western Australia. In the past, helicoverpa was managed primarily by chemical control tactics that consisted of ground applications of broad-spectrum insecticides such as methomyl, alpha-cypermethrin and esfenvalerate, which are highly toxic to a suite of beneficial insect species including trichogramma, lacewings, ladybirds, predatory mites and predatory bugs (Kopperts Biological Resources 2008). Within the last few years, growers have adopted a range of control tactics that include releases of the wasp *Trichogramma pretiosum* and application of reduced risk insecticides such as Gemstar (nuclear polyhedrosis virus (NPV)). By using selective insecticides to target specific pests such as helicoverpa, or group of pests such as Lepidoptera, the status of other pests in sweet corn may have changed. Naturally occurring beneficial species that were previously killed by broad spectrum insecticides may have also increased the level of biological control of helicoverpa and other insect pests, as has occurred in other cropping systems (Johnson and Tabashnik 1999).

In South Queensland, there are a range of secondary pests (aphids, mites and thrips) which have now become major pests, as the sweet corn industry is largely using narrow spectrum insecticides for the management of helicoverpa. A similar situation to this has occurred in other cropping systems (cotton, Brassica vegetables and tomatoes), whereby secondary pests, which were once easily controlled by broad spectrum insecticides, have become more important to these industries as more biologically based IPM systems have been widely adopted. In south east Queensland helicoverpa is predominantly an issue for growers during the first half of the growing season when beneficial insect numbers are low, in particular the trichogramma egg parasitoid, which when in sufficient numbers eliminates the need for insecticide sprays for helicoverpa management. However, if growers use broad spectrum insecticides repeatedly, such beneficial insects are drastically reduced to the point where helicoverpa once more becomes an issue, especially during the later part of the growing season. To this end the use of soft option insecticides is vitally important and the need for additional insecticides to those currently registered will help slow down any resistance developing and prolong the use of those insecticides that are soft against beneficial insects. The need to manage 'secondary' pests, whilst maintaining and/or improving the management of helicoverpa, has become the focus of this current project and in particular in the south east region of Queensland.

In North Queensland, helicoverpa is a regular pest and corn aphid, *Rhopalosiphum maidis,* and two-spotted spider mite, *Tetranychus urticae* are seasonal pests. Corn aphids are prevalent during cooler months (May to Aug) while mite population increase later in the season (Sep to Dec). As part of this sweet corn project a number of potentially new insecticides for helicoverpa management supplied by Bayer CropScience, DuPont Australia and Sumitomo Chemicals were evaluated for the control of helicoverpa and other lepidopteran pests with a look at a number of sap sucking insect pests as well as their effect on beneficial insect numbers in the field.

In North Queensland, sweet corn is grown in the Bowen/ Burdekin region where around 2,000 ha is grown for the fresh market, with an estimated value of $30 million. The sweet corn production season starts in March and ends in November. The corn earworm or helicoverpa (*Helicoverpa armigera*) is a major pest of sweet corn in the region. Helicoverpa occurs throughout the season but is more active during autumn and spring. This pest has traditionally been managed by applying broad-spectrum insecticides, but is more difficult to control with carbamate and organophosphate insecticides because of widespread resistance problems. In the recent years the introduction of narrow spectrum insecticides spinosad and NPV provided better management of helicoverpa and reduced the reliance on broad-spectrum products.

Some of the new generation insecticides being developed are ideal for inclusion in IPM programs because they control helicoverpa while less harmful to beneficial arthropods. The action of these beneficials supplements the mortality caused by the insecticide, and can contribute to the effective control of helicoverpa.

Aphids and mites are now recognised as seasonal pests on sweet corn in North Queensland. In cooler conditions, aphids colonise the crop rapidly, while mite outbreaks normally occur in warmer months. Aphids often cause direct feeding damage and remove the plant sap, which reduces plant vigour and contaminates the cobs. The sticky honeydew excretions are difficult to remove and black sooty mould grows on them, making the cobs unmarketable. There are two aphid species which infest sweet corn but the corn aphid *Rhopalosiphum maidis* is the predominant species in the region.

Aphid control in sweet corn has become more difficult recently. In the past few years, control failures have been reported with organophosphate and carbamate insecticides. Only one insecticide, dimethoate is registered in sweet corn for use against aphids. Of particular concern to the sweet corn industry, is the fact that the long-term availability of dimethoate is very uncertain. Products containing dimethoate and all associated labels are being reviewed because of toxicological, occupational health and safety and residue concerns. The loss of dimethoate would leave industry without specific insecticides for aphid control in sweet corn.

## 3.30 Purpose for the Research.

The need to manage 'secondary' pests and diseases, whilst maintaining and/or improving the management of helicoverpa, was identified by the sweet corn industry in May 2001 (at the completion of VG97036) - "While integrated pest management (IPM) of the caterpillar pest, helicoverpa is a reality in sweet corn crops, a reduction in the use of broad spectrum pesticides for helicoverpa management has lead to this increase in the number of other pests which are now damaging sweet corn crops. Pests such as thrips, aphids and dried fruit beetles are contaminants in produce bound for export markets. Other caterpillar species, plant hoppers, mites and green vegetable bug are causing physical damage to the crop." - extract from the Final Report Project - VG97036."

Subsequently the IPM project, "Improved IPM Systems in the Australian Sweet Corn Industry" – VG05025 was funded to build on the outcomes of VG97036 and to further understand the complexity of IPM in sweet corn, by focussing on the broader range of pests and diseases, and their management in an IPM context.

Some of these secondary pests of sweet corn have yield reducing effects, and others are contaminants in product destined for both domestic and export markets. The effects are product rejection (an export and domestic market access issue), downgrading and/or reduced $ returns, and reduced marketable yields.

The work program included an assessment of new "soft options" as additional components of Integrated Pest Management; Identifying naturally occurring beneficial organisms (natural enemies) which have the potential to contribute to sweet corn IPM systems; Developing and testing improved IPM strategies, which may include new "soft options" and the enhancement of naturally occurring beneficials.

## 3.40 Significance for the Industry.

In 1997 a project, "Insect Pest Management in Sweet Corn" – VG97036, was funded by HAL, and included team members and work programs in Queensland, NSW, Victoria and Tasmania, with linkages into WA. This project aimed to reduce the risks of crop loss from insect damage, mainly *Helicoverpa armigera* (helicoverpa), and improve production and quality in sweet corn aimed at domestic (fresh and processing) and export markets.

An evaluation of this project in 2001 showed that the Australian sweet corn industry widely adopted the outcomes of VG97036, which concentrated on managing the main pest, helicoverpa.
A range of secondary pests (aphids, mites and thrips) had become major pests, as the sweet corn industry, especially in Queensland, largely used narrow spectrum insecticides for the management of helicoverpa. This is a situation which has occurred in other cropping systems (cotton, Brassica vegetables and tomatoes), whereby secondary pests, which were once easily controlled by broad spectrum insecticides, have become more important to these industries as more biologically based IPM systems have been widely adopted.

## 3.50 Aims of the Project.

Improve Integrated Pest Management (IPM) systems currently being used in the Australian Sweet Corn Industry for the management of a range of 'secondary pests' whilst maintaining or improving helicoverpa management. Whilst Integrated Pest Management of the caterpillar pest helicoverpa, is a reality in the majority of sweet corn crops in Australia, a reduction in the use of broad spectrum pesticides has led to an increase in the number and the effects of other pests. Pests such as thrips, aphids and dried fruit beetles are contaminants in produce bound for domestic and export markets. Other caterpillar species, plant hoppers, mites and green vegetable bug are causing physical damage to the crop.

## 3.60 Project Strategy.

To achieve the aims, a work program was developed at each of the project nodes to assess new "soft options", as additional components of IPM, for managing a range of sweet corn pests; and promote project outcomes, and disseminate information to the industry through the IDO Network and farm-walks.

Because the sweet corn industry in the Riverina has not widely adopted the available 'soft options' for the management of helicoverpa, the aims of the NSW studies were to conduct trials to assess the efficacy of different spray programmes that were based either on new generation, narrow spectrum chemicals or older broad spectrum chemicals for controlling helicoverpa, and comparing these two spraying programmes with the typical spray program followed by local sweet corn growers who use broad spectrum insecticides to produce corn for the processing market.

The aims of the Western Australian study were to, identify the primary and secondary pests occurring in sweet corn in Western Australia, quantify their infestation levels; identify naturally occurring beneficials, and document current monitoring and control methods.

The aims of the South Queensland studies were to manage 'secondary' pests, whilst maintaining and/or improving the management of helicoverpa. A number of potentially new insecticides for helicoverpa management supplied by Bayer CropScience, DuPont Australia and Sumitomo Chemicals were evaluated for the control of helicoverpa and other lepidopteran pests together with a number of sap sucking insect pests including their effect on beneficial insect numbers in the field.

In this study, pest management in sweet corn in North Queensland has focused on improving helicoverpa management within the existing IPM system, identifying the key secondary pests occurring in sweet corn and developing manage strategies to reduce crop losses.

## Disclaimer:

***A range of insecticides are referred to in this report. Where an insecticide is named together with ™ as a superscript, this refers to the insecticides' Registered Trade Name. This DOES NOT imply that this insecticide is registered for use on sweet corn in Australia. It is important that the registration status of all insecticides are verified prior to their application to sweet corn in Australia.***

# 4.00 Materials & Methods

## 4.10 Soft Options Assessment – Materials & Methods.

**Soft Options (or Narrow Spectrum Pesticides)** are an important component of IPM systems. A number of narrow spectrum insecticides have been made available to the project team through three chemical companies, Bayer CropScience, DuPont Australia and Sumitomo Chemicals – each product has been allocated a project code, as not all of these soft options products are registered in Australia (see Table below).

| Chemical Company | Company Code | Active Ingredient | Trade Name | Project Code |
|---|---|---|---|---|
| Bayer | NNI0001 | flubendiamide | Belt 480 SC | SCLI-01 |
| | BYI8330 | spirotetramat | Movento 240SC | SCSI-01 |
| DuPont | DPX-E2Y45 SC | chlorantraniliprole | Coragen 200 SC | SCLI-02 |
| | DPX-HGW86 | | Soyate 100 SC | SCSI-02 |
| Sumitomo | S-1812 | pyridalyl | Symphony 500 EC | SCLI-03 |
| | TI-435 | clothianidin 200SC | | SCSI-03 |
| | TI-435 | clothianidin 500WG | | |
| | | etoxazole | Paramite 110 SC | Mite-01 |

The project work program has concentrated on the assessment of new "soft options" as additional components of Integrated Pest Management, and assessing the effects of these soft options on naturally occurring beneficial organisms (natural enemies) which have the potential to contribute to sweet corn IPM systems. These have also been the subjects of detailed Milestone Reports (see Appendices 4 & 5).

The trials in Qld and NSW were conducted from 2005 to 2007 to determine the efficacy of these 'soft options' against *Helicoverpa armigera* and secondary pests including thrips, aphids and mites.

### 4.11 New South Wales - Evaluating spray programs for the control of pests in sweet corn – Materials & Methods

**a) 2005-06 Trials**

Two trials were conducted during the 2005/06 season to assess the efficacy of a range of insecticides in controlling helicoverpa in sweet corn. Success™ (spinosad) was included in the study as the industry standard.

The first trial was conducted at the Yanco Agricultural Institute, NSW, in a small field of sweet corn specifically grown for the efficacy trial. The trial area was 12 beds wide and 80m long. The crop was sown on 25th November 2005 and harvested on 13th February 2006.

The second trial was conducted on a large commercial property near Whitton, NSW. A small field of sweet corn was established as the trial area within a commercial crop of maize. The sweet corn field was 5 beds wide and 200m long. The crop was sown on the 26th November 2005 and harvested on 20th February 2006.

Jubilee was the variety used for both trials. The Yanco trial was irrigated by overhead sprinklers. The Whitton trial was furrow irrigated.

Trial design

The Yanco trial had four replicates of eight treatments in a randomised block design. Each plot was one plant row wide (0.75m) and 18m long. There were two plant rows (1.5m) between plots as buffers and 2m of buffer at the end of rows. Only the middle 15m of each plot were used for assessments.

Table 1: Yanco trial design

| | | | | |
|---|---|---|---|---|
| 6 | 1 | 4 | 8 | Rep 1 |
| 7 | 5 | 2 | 3 | |
| 3 | 4 | 5 | 6 | Rep 2 |
| 1 | 7 | 8 | 2 | |
| 5 | 8 | 3 | 1 | Rep 3 |
| 2 | 6 | 7 | 4 | |
| 8 | 2 | 1 | 7 | Rep 4 |
| 4 | 3 | 6 | 5 | |

The Whitton trial had four replicates of eight treatments in a randomised block design. Each plot was one plant row wide (0.9m) and 15m long. There were two plant rows (1.8m) between plots as buffers and 2m of buffer at the end of rows. Only the middle 12m of each plot were used for assessments.

Table 2: Whitton trial design

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 2 | 5 | 2 | 7 | 8 | 3 | 4 | 1 | 6 | 5 | Rep 2 |
| 6 | 3 | 8 | 5 | 1 | 3 | 7 | 2 | 6 | 8 | 4 | Rep 3 |
| | 1 | 7 | 6 | 4 | 7 | 5 | 1 | 8 | 2 | 3 | Rep 4 |

Rep 1

Treatments

Table 1a: Treatments for both Yanco and Whitton trials

| Insecticide | Rate |
|---|---|
| • (1) Untreated | |
| • (2) SCLI-02 (Low rate) | 20 g/ha of active ingredient |
| • (3) SCLI-02 (High rate) | 40 g/ha of active ingredient |
| • (4) SCLI-01 (Low rate) | 100 ml/ha |
| • (5) SCLI-01 (High rate) | 150 ml/ha |
| • (6) SCLI-03 | 1.25 L/ha |
| • (7) Avatar™ (indoxacarb 400 g/kg) | 170 g/ha |
| • (8) Success™ (spinosad 120 g/L) | 800 ml/ha |

Trial Schedule and Procedures

Table 2: Schedule for the Yanco trial.

| Date | Activity | Crop stage |
|---|---|---|
| 24 Jan 06 | Initial assessment | 100% silking |
| 24 Jan 06 | 1st spray treatment | 100% silking |
| 30 Jan 06 | 2nd spray treatment | 1 week after silking |
| 7 Feb 06 | 3rd spray treatment | 2 weeks after silking |
| 13 Feb 06 | Harvest | 74 days (68% kernel moisture) |
| 14 Feb 06 | Final assessment | |

Note: It would have been preferred to start spray treatments one week earlier when the crop was at early tasselling. This was not done due to one of the insecticides (treatments) not being available until the 23/Jan/06.

Table 3: Schedule for Whitton trial.

| Date | Activity | Crop stage |
|---|---|---|
| 23 Jan 06 | Initial assessment | Early tasselling |
| 23 Jan 06 | 1st spray treatment | Early tasselling |
| 01 Feb 06 | 2nd spray treatment | 100% tasselling |
| 06 Feb 06 | 3rd spray treatment | 1 week after silking |
| 10 Feb 06 | 4th spray treatment | 2 weeks after silking |
| 20 Feb 06 | Harvest | 86 days (70% kernel moisture) |
| 22 Feb 06 | Final assessment | |

***Equipment***

All treatments were sprayed using a 15L Silvan backpack sprayer attached to a hand held boom. The boom was equipped with six TXV-3 cone jet nozzles and was operated by spraying both sides of the plant line in separate passes to give maximum spray coverage. The output volume was 312 L/ha.

Statistical analysis

Data were analysed by ANOVA for the random block design. If significant differences ($P < 0.05$) in plot totals were detected among the treatments, the treatment means were separated by Tukey's test.

Beneficial insects

During early crop inspections at the Yanco trial site, a range of beneficial insects were observed. Actual numbers were not recorded but was considered high enough to have an effect on helicoverpa numbers. To reduce the effect of the beneficial insects on the efficacy trial, a spray treatment of dimethoate was applied at 800 ml/ha. The dimethoate was applied to the entire trial area on the 17th January 2006, before spray treatments commenced. No beneficial insects were seen during early crop inspections at the Whitton trial site, so no beneficial insect control measures were applied.

Assessments

The initial assessment for both trials involved checking a random 10 plants in each plot for helicoverpa eggs and helicoverpa larvae (2 plants side by side at 5 random locations within the plot). The final harvest assessment was conducted when the grain moisture fell to 70% (approximate kernel moisture requirement when grown for processing). Harvest assessment was conducted on 50 random cobs per plot for the Yanco trial and 60 random cobs for the Whitton trial. The cobs were checked at harvest for the presence of helicoverpa larvae and larvae damage to the cobs.

Table 4: Assessments conducted at harvest

| Assessment count | Code | Description |
|---|---|---|
| Nil damage | Nil Dam | Number of cobs without any grub damage |
| Tip damage | Tip Dam | Number of cobs with grub damage to the tip of the cob |
| Side damage | Side Dam | Number of cobs with grub damage to the side of the cob. (Tip damage may or may not be present[1]) |
| Total damage | Tot Dam | Number of cobs with any type of grub damage. (this is the sum of "Tip Dam" and "Side Dam") |
| Number of grubs | Grub # | The total number of grubs found on the cobs |

[1] Side damage to a sweet corn cob is considered worst than tip damage as the cob cannot be trimmed.

### b) 2006-07 Trials

Two trials were conducted during the 2006/07 season to assess the efficacy of a range of insecticides in controlling helicoverpa in sweet corn. Success™ (spinosad) was included in the study as the industry standard.

The first trial was conducted at the Yanco Agricultural Institute, NSW, in a small field of sweet corn specifically grown for the efficacy trial. The trial area was 12 beds wide and 80m long. The crop was sown on 13th December 2006 and harvested on 5th March 2007.

The second trial was conducted on a large commercial property near Whitton, NSW. A small field of sweet corn was established as the trial area within a commercial crop of maize. The sweet corn field was five beds wide and 200m long. The crop was sown on the 15th December 2006 and harvested on 6th March 2007.

Jubilee was the variety used for both trials. The Yanco trial was irrigated by overhead sprinklers. The Whitton trial was furrow irrigated.

<u>Trial design</u>

The Yanco trial had four replicates of seven treatments in a randomised block design. Each plot was one plant row wide (0.75m) and 18m long. There were two plant rows (1.5m) between plots as buffers and 2m of buffer at the end of rows. Only the middle 15m of each plot were used for assessments.

Table 5: Yanco trial design

| | | | |
|---|---|---|---|
| 6 | 1 | 4 | 7 |
| 3 | 5 | 2 | 6 |
| 1 | 4 | 5 | 2 |
| 5 | 6 | 7 | 1 |
| 5 | 7 | 3 | 4 |
| 7 | 2 | 6 | 3 |
| 4 | 3 | 1 | 5 |
| Rep 4 | Rep 3 | Rep 2 | Rep 1 |

The Whitton trial had four replicates of six treatments in a randomised block design. Each plot was one plant row wide (0.9m) and 18m long. There were two plant rows (1.8m) between plots as buffers and 2m of buffer at the end of rows. Only the middle 15m of each plot were used for assessments.

Table 6: Whitton trial design

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3 | 4 | 1 | 4 | 2 | 5 | 3 | 6 |
| 2 | 5 | 3 | 2 | 6 | 1 | 5 | 4 |
| 6 | 1 | 6 | 5 | 4 | 3 | 2 | 1 |
| Rep 4 | | Rep 3 | | Rep 2 | | Rep 1 | |

<u>Treatments</u>

Table 7: Treatments for both Yanco and Whitton trials

| Insecticide | Rate | Wetter |
|---|---|---|
| • (1) Untreated | | |
| • (2) SCLI-02 (Without wetter) | 100 ml/ha | Nil |
| • (3) SCLI-02 (With wetter) | 100 ml/ha | Agral™ at 25ml/100L |
| • (4) SCLI-01 (Low rate) | 100 ml/ha | Agral™ at 25ml/100L |
| • (5) SCLI-01 (High rate) | 150 ml/ha | Agral™ at 25ml/100L |
| • (6) Success™ (spinosad 120 g/L) | 800 ml/ha | Agral™ at 25ml/100L |
| • (7) Avatar™ (indoxacarb 400 g/kg)* | 250 g/ha | Agral™ at 25ml/100L |

* Avatar™ was only applied in the Whitton trial

<u>Trial schedule and procedures</u>

Table 8: Schedule for both trial sites

| Date | Activity |
|---|---|
| 31 Jan 07 | Initial assessment at Yanco site (10% silking) |
| 01 Feb 07 | Initial assessment at Whitton site (80% silking) |
| 05 Feb 07 | First spray treatment at Yanco site |
| 06 Feb 07 | First spray treatment at Whitton site |
| 14 Feb 06 | Second spray treatment at Whitton site |
| 14 Feb 07 | Second spray treatment at Yanco site |
| 20 Feb 06 | Third spray treatment at Whitton site |
| 22 Feb 07 | Third spray treatment at Yanco site |
| 05 March 07 | Harvest Yanco trial |
| 06 March 07 | Harvest Whitton trial |
| 06 March 07 | Cob assessment for Yanco trial |
| 07 March 07 | Cob assessment for Whitton trial |

<u>Equipment</u>

All treatments were sprayed using a 15L Silvan backpack sprayer attached to a hand held boom. The boom was equipped with four TXV-3 cone-jet nozzles and was operated by spraying both sides of the plant line in separate passes to give maximum spray coverage. The output volume was 305 L/ha.

Statistical analysis

Data was analysed by ANOVA for the random block design. If significant differences ($P < 0.05$) in plot totals were detected among the treatments, the treatment means were separated by Tukey's test.

Assessments

The initial assessment for both trials involved checking ten random plants in each plot for helicoverpa eggs and helicoverpa larvae (two plants side by side at five random locations within the plot). The final harvest assessment was conducted when the grain moisture fell below 70% (approximate kernel moisture requirement when grown for processing). Harvest assessment was conducted on 40 random cobs per plot for the Whitton trial and between 30 and 50 random cobs for the Yanco trial. It was planned to harvest 50 cobs per plot at Yanco but was not possible due to some plots with a low plant stand and a high level of boil smut within the whole trial. The cobs were checked at harvest for the presence of helicoverpa larvae and larvae damage to the cobs.

Table 9: Assessments conducted at harvest

| Assessment count | Code | Description |
|---|---|---|
| Nil damage | Nil Damage | Number of cobs without any grub damage |
| Slight tip damage | Slight Damage | Number of cobs with only a small amount of grub damage to the tip of the cob |
| Marketable cobs | Marketable | Cobs still marketable for processing (this is the sum of "Nil Dam" and "Slight Dam") |
| Heavy tip damage | Heavy Damage | Cobs with tip damage bad enough that it becomes unmarketable for processing |
| Side damage | Side Damage | Number of cobs with grub damage to the side of the cob (tip damage may or may not be present[1]) |
| Number of grubs | Grub # | The total number of grubs found on the cobs |

[1]Side damage to a sweet corn cob is considered worst than tip damage as the cob cannot be trimmed.

### c) Additional 2007 non-replicated Trial

In February and March of 2007 the efficacy of two new Lepidoptera insecticides (SCLI-01 and SCLI-02), were compared in their ability to control helicoverpa in sweet corn with alpha cypermethrin and a control treatment of no spray. Efficacy against helicoverpa and some common beneficial insect species was investigated in a **non-replicated** trial at Yanco Agricultural Institute NSW. Alpha cypermethrin was chosen as the third spray treatment because it is known to be toxic against most beneficial insects and would provide a good comparison to the new chemistries which are more selective.

A small block of Jubilee sweet corn was planted specifically for this trial on the 12th December at Yanco Agricultural Institute, Yanco, Riverina, NSW and harvested on the 1st March 2007.

Irrigation method:

Over head sprinklers were used with frequency and volume determined according to crop requirements.

Table 10: Block Layout:

| | |
|---|---|
| Alpha cypermethrin | Control |
| SCLI-01 | SCLI-02 |

Blocks were 38m long and 4 ½ beds (6.74m) wide = 256.5m² with 4 meters of unplanted buffers between the plots. Block size was designed to be large enough to reduce insect population movement between the treatment blocks. Treatments were not replicated.

Application equipment, rates and dates:

Two applications of each treatment were applied to each of the three insecticide treated plots. The control plot had no insecticide applications. Applications were applied on the 7th and 13th of February. Each treatment was applied with 305L of water/ha with Agral™ added as the adjuvant at 25ml/100L water. All treatments were sprayed using a 15L Silvan backpack sprayer attached to a hand held boom. The boom was equipped with four TXV-3 cone- jet nozzles and was operated by spraying both sides of the plant line to give optimum spray coverage.

Table 11: Treatment application rates.

| **Treatment** | **Rate (ml/ha)** |
|---|---|
| SCLI-02 | 100 |
| SCLI-01 | 150 |
| Alpha cypermethrin | 400 |
| Control | NA |

Assessment and monitoring.

Two in-field pre-treatment monitoring inspections were conducted prior to the initial spray application. These inspections were conducted on the 31st of January and the 6th of February. Results from this period prior to the spray applications are referred to as pre-treatment results. Field monitoring assessments continued weekly following the initial spray application which was applied on the 7th February. Data has been presented in this report in reference to the time past since the initial spray application, see table below.

Table 12: Monitoring and assessment dates.

| Timing | Date | Crop stage |
|---|---|---|
| Pre-treatment | Data from 31st January and 6th February 2007 was combined and averaged for pre-treatment results. | Early tasselling |
| Spray one | 7th February | Tasselling |
| Wk1 | 12th Feb | Silking |
| Spray two | 13th Feb | Silking |
| Wk2 | 19th Feb | Silking |
| Wk3 | 26th Feb | Cob filling |
| Wk4 | 1st March | Harvest assessment |
| Wk5 | 8th March | Post harvest |

Twenty plants in each plot were monitored in the field weekly except for in week four when the harvest assessment was conducted. Four groups of five plants were randomly chosen for monitoring. Each plant was monitored for pest and beneficial insects. Each plant was inspected from soil level to the tip, excluding tillers; only the main stem was inspected from top to bottom. Sticky traps were present in each plot and replaced weekly. helicoverpa eggs (excluding the freshly laid eggs) were collected and observed for parasitism in the lab. Harvest assessment was conducted during week four, sticky traps were not collected during this week and no field monitoring was conducted. Insect counts for week four were obtained from the harvest assessment where sixty cobs per treatment were harvested into bags and transferred to the lab for assessment. All insects found in the bag and on the cobs were recorded for each treatment.

### d) 2007-08 Trials

Two trials were conducted during the 2007/08 season to assess the efficacy of different spray programmes that were based either on new generation, narrow spectrum chemicals or older broad spectrum chemicals for controlling helicoverpa. Two spray programs (treatments) evaluated the use of SCLI-02 when first applied at silking. Both of these programs involved rotating with Success™ and one also included an earlier application of Avatar™ at tasselling. The effectiveness of these two spraying programmes was compared to the typical spray program followed by local sweet corn growers who use broad spectrum chemicals to produce corn for the processing market. In addition, the grower's spray program was evaluated at both high and low water rates. The low water rate was applied to simulate a standard "over the top" boom spray application. The high water rate was applied to simulate a boom fitted with droppers to help improve spray coverage to the target area. The spray treatments were also compared with a nil spray program where no spray treatments were applied.

Location and Time

The two trials were conducted at the Yanco Agricultural Institute, NSW, in a small field of sweet corn specifically grown for the trials. Each trial area was 12 beds wide and 80m long. Both crops were sown on 21 November 2007 and harvested on 5 February 2008.

Variety and Irrigation Method

Both trials were sown with the variety Krispy King and irrigated by overhead sprinklers.

**Trial Design**

The trials had four replicates of five treatments in a randomised block design. Each treatment plot was a single plant row on a 1.5m bed and 18m long. There were two plant rows between plots as buffers and 2m of buffer at the end of rows. Only the middle 15m of each plot were used for assessments.

Table 13: Trial 1

| | | | |
|---|---|---|---|
| T5 | T4 | T3 | T1 |
| T3 | T1 | T2 | T5 |
| T1 | T2 | T5 | T4 |
| T4 | T3 | T1 | T2 |
| T2 | T5 | T4 | T3 |
| Rep 4 | Rep 3 | Rep 2 | Rep 1 |

Table 14: Trial 2

| | | | |
|---|---|---|---|
| T4 | T1 | T3 | T2 |
| T2 | T4 | T5 | T1 |
| T3 | T5 | T2 | T4 |
| T5 | T2 | T1 | T3 |
| T1 | T3 | T4 | T5 |
| Rep 4 | Rep 3 | Rep 2 | Rep 1 |

Table 15: **Treatments**

| Treatment | Spray control program |
|---|---|
| T1 | Avatar™ applied when tassels first appear. SCLI-02 or Success™ then to be used in rotation if pest thresholds are reached. |
| T2 | SCLI-02 to be applied when the crop first starts silking. SCLI-02 or Success™ then to be used in rotation if pest thresholds are reached. |
| T3 | A tank mix of Dominex™ and Lannate™ to be applied when tassels first appear. A second tank mix of Dominex™ and Lannate™ to be applied one week later. Success then to be rotated with Dominex™ and Lannate™ if pest thresholds are reached. |
| T4 | Similar program to T3 with a lower water rate. This treatment mimics the program used by local growers supplying the processing market. |
| T5 | Control - No insecticides applied |

Note: A spray threshold of 3 grubs or 8 eggs per 20 plants was used

Table 1 displays the chemicals and rates used in both trials.

Table 16: Chemicals used in both trials

| Trade Name | Active | Rate/Ha |
|---|---|---|
| SCLI-02 | Rynaxypyr (200g/L) | 100ml |
| Success™ | Spinosad (120 g/L) | 800ml |
| Avatar™ | Indoxacarb (300 g/kg) | 250g |
| Lannate™ | Methomyl (225 g/L) | 2000ml |
| Dominex™ | Alpha-cypermethrin (100 g/L) | 400ml |

Note: Agral™ was used as a wetter for all treatments at a rate of 25ml/100L

Trial schedule and procedures

Table 17: Schedule for both trial blocks

| Date | Crop stage | Activity |
|---|---|---|
| 21 Nov 07 | | • Crop sown |
| 10 Jan 08 | | • Monitor for insect pests only |
| 11 Jan 08 | 50% tasselling | • Spray T1 with Avatar™<br>• Spray T3 & T4 with a tank mix of Dominex™ and Lannate™. |
| 15 Jan 08 | 51 DAS | • Monitor for insect pests only |
| 15 Jan 08 | 100% tasselling and 50% silking | • Spray T1 & T2 with SCLI-02 |
| 17 Jan 08 | 52 DAS | • Monitor for insect pests only |
| 18 Jan 08 | 100% silking | • Spray T1 & T2 with SCLI-02<br>• Spray T3 & T4 with a tank mix of Dominex™ and Lannate™. |
| 21 Jan 08 | 55 DAS | • Monitor for insect pests only |
| 23 Jan 08 | 57 DAS | • Spray all four treatments with Success™. |
| 24 Jan 08 | 58 DAS | • Monitor for insect pests and beneficials |
| 25 Jan 08 | 59 DAS | • Spray T1 & T2 with SCLI-02<br>• Spray T3 & T4 with a tank mix of Dominex™ and Lannate™. |
| 29 Jan 08 | 63 DAS | • Monitor for insect pests and beneficials |
| 05 Feb 08 | 72% grain moisture<br>70 DAS | • Harvest |

Note: DAS = Days After Sowing

**Equipment**

Treatments T1, T2 and T3 were sprayed using a 15L Silvan backpack sprayer attached to a hand held boom, equipped with four TXV-3 cone-jet nozzles. The boom was operated by spraying both sides of the plant line in separate passes to give maximum spray coverage with an output volume of 276 L/ha. This spray operation was conducted to simulate commercial spray operations of boom sprays fitted with droppers.

Treatment T4 was sprayed using a 15L Silvan backpack sprayer attached to a hand held boom, equipped with two TXV-6 cone-jet nozzles. The boom was operated by spraying over the top of the plant line in a single pass to give an output volume of 138 L/ha. This spray operation was conducted to simulate commercial spray operations with a standard over top boom spray.

No measurement was made, but it is understood that the TXV-3 nozzles would produce a smaller droplet size than the TXV-6 nozzles as the operating pressure was kept constant. It is estimated that the TXV-3 nozzles produced droplets with an average size of 100µm (VMD) and the TXV-6 nozzle produced droplets with an average size of 150µm.

**Statistical analysis**

Data was analysed by ANOVA for the random block design. If significant differences ($P < 0.05$) in plot totals were detected among the treatments, the treatment means were separated by LSD test.

**Assessments**

The first scouting involved checking five random plants per plot in Trial 1 (i.e. 20 plants per treatment) and ten random plants per plot in Trial 2 (i.e. 40 plants per treatment). These assessments involved checking for helicoverpa eggs and larvae. Subsequent scouting for helicoverpa involved checking ten random plants per plot in both trials.

The final two scouting assessments involved checking ten random plants per plot (i.e. 40 plants per treatment) in both trails for all pests and beneficial insects.

The final harvest assessment was conducted when the kernel moisture was 73% (approximate kernel moisture requirement when grown for processing). Harvest assessment was conducted on 40 random cobs per plot (160 cobs per treatment). The cobs were checked at harvest for the presence of helicoverpa larvae and larvae damage to the cobs.

Table 18: Assessments conducted at harvest

| Assessment criteria | Code | Description |
|---|---|---|
| No damage at all | Nil Damage | Number of cobs without any grub damage |
| Very Little Damage | Very little Damage | Number of cobs with only a small amount of grub damage to the tip of the cob (1 or 2 damaged kernels per cob) |
| Little to medium Damage | Small Damage | Number of cobs with tip damage bad enough to cause the cob to be unsuitable for fresh market (3 to 12 damaged kernels per cob) |
| Heavy damage | Heavy Damage | Number of cobs with tip damage bad enough that it becomes unsuitable for fresh market and processing (up to 40mm of damage to the tip of cob) |
| Very heavy damage | Very Heavy Damage | Number of cobs with very bad tip or side damage bad enough that it becomes unsuitable for fresh market and processing |
| Number of grubs | Grub # | The total number of grubs found on the cobs |

The five assessment categories can be grouped into three categories based on the cobs marketability. Cobs for the fresh market should have nil to very little grub damage, and belong to the category: "marketable for fresh market". Cobs for the processing market can tolerate a little more damage as the tips can be trimmed back. The category "marketable for processing" consists of cobs with no damage, little damage and small damage. Cobs with too much grub damage as either a fresh product or for processing are not suitable for sale at any market. These assessment categories are only generalisations but make a useful way to evaluate the different treatments.

Table 19: Assessment counts grouped into marketable categories

| Assessment criteria | Code | Description |
|---|---|---|
| No damage to very little damage | Marketable for fresh market | Cobs marketable for the fresh market (This is the sum of "Nil Damage " and "Very little Damage") |
| No damage to small amount of damage | Marketable for processing | Cobs marketable for the processing market (This is the sum of "Nil Damage", "Very little Damage" and "Small damage") |
| Heavy to very heavy damage | Unmarketable | Cobs unsuitable for any market (This is the sum of "heavy damage" and "very heavy damage") |

## 4.12 North Queensland - Soft Options Assessment – Materials & Methods

Four field trials were established during the 2006 and 2007 cropping seasons in Bowen, to evaluate a number of narrow spectrum insecticides and miticides against helicoverpa, aphids and mites.

The trials were conducted on the DPI&F Research Station, Bowen, Queensland from May to November in order to expose the crop to various pest pressures. Each trial area consisted of 16 rows, which were 80m long and spaced 75 cm apart. All experimental plots were grown with the trickle irrigation system and irrigated at weekly intervals until final harvest.

The sweet corn variety Golden Sweet was directly seeded in all four trials. Insecticide treatments were arranged in a randomised complete block design with three replicates.

### a) Field Trial 1 – Materials & Methods

The trial was planted on 25 May 2006 to evaluate the "soft option" insecticides against helicoverpa and aphids. The insecticide treatment details are summarised in Table 20. Insecticides were applied at fresh silk stage (on 28 Jul 06) using a motorised Knapsack sprayer fitted with two flat-fan nozzles (DG80015). The spray volume of 400 L/ha was used to target silks and tassels.

**Table 20: Insecticide treatments applied in Trial 1 (2006)**

| Insecticides | Active ingredient | Formulations | Application rate | Target pest |
|---|---|---|---|---|
| SCLI-01 | Flubendiamide | 480g/L SC | 48 g ai/ ha | helicoverpa |
| SCLI-02 | Chlorantraniliprole | 200g/L SC | 20 g ai/ ha | helicoverpa |
| SCLI-02 | Chlorantraniliprole | 200g/L SC | 40 g ai/ ha | helicoverpa |
| SCLI-03 | Pyridalyl | 500 g/ L EC | 100 g ai/ ha | helicoverpa |
| Avatar™ | Indoxacarb | 400g/ kg WG | 100 g ai/ ha | helicoverpa |
| SCSI-01 | Spirotetramat | 240 g/ L SC | 48 g ai/ ha | Aphids |
| Untreated | Nil | Nil | Nil | helicoverpa/ Aphids |

Assessment: Trial plots were monitored at 10 to 14 day intervals for helicoverpa eggs and larvae, aphids, mites and beneficial insects. At harvest, 20 cobs per plot were harvested from the middle two rows. The cobs were assessed for helicoverpa damage and product marketability according to the criteria listed in Table 21. Also aphid damage and infestation levels were assessed as described in the Table 22.

**Table 21: Cob assessment criteria for helicoverpa damage and product marketability**

| Damage Category | Description | Marketable Category |
|---|---|---|
| Nil damage | NO damage to cob but with slight silk damage | Fresh Market |
| Tip damage | Tip damage up to 4cm or deep silk damage | Pre-packet Market (Tips can be trimmed and marketed) |
| Deep damage | Damage over 5 cm deep or grub present well inside the cob | Unmarketable |

**Table 22**: **Cob assessment criteria for aphid infestation and product marketability**

| Aphid infestation levels | Marketability |
|---|---|
| Nil Infestation - No aphids or contamination in the cobs | Fresh Market - No infestation or few aphids present only outer husks and easily removable |
| Slight Infestation – up to 25 aphids on outer cover of the cobs or light contamination | Pre-Packet market 10 - 25 aphids on outer surface of husk and easily washable |
| Heavy Infestation - Over 25 aphids on the cobs and/or honeydew and stickiness on cobs | Unmarketable – Heavy aphids or high contamination and hard to remove during the washing |

**b) Field Trial 2 – Materials & Methods**

This trial was planted on 8 Aug 2006 to target mite and helicoverpa during the spring months. The insecticide treatments are summarised in Table 23. SCSI-03 was applied at planting as a soil drench. Foliar sprays were applied at the early silk stage (on 5 Oct 06) using a motorised Knapsack sprayer fitted with two flat-fan nozzles (DG80015). A spray volume of 600 L/ha was used to cover both sides of the plant row.

Assessment: Trial plots were monitored at 7 to 10 day intervals for helicoverpa eggs and larvae, aphids, mites and beneficial insects. Three weeks after the spray, 10 leaves per plot were collected to assess mite and predator densities. Leaf samples were taken to the laboratory where 3 x 1cm$^2$ areas were selected on each leaf and all mite stages and *Stethorus* (mite-eating ladybird larvae) were counted under microscope.

**Table 23: Insecticide treatments applied in Trial 2 in 2006**

| Insecticides | Active ingredient | Formulations | Application rate | Target pest |
|---|---|---|---|---|
| SCLI-01 | Flubendiamide | 480g/L SC | 48 g ai/ ha | helicoverpa |
| SCLI-02 | Chlorantraniliprole | 200g/L SC | 10 g ai/ ha | helicoverpa |
| SCLI-02 | Chlorantraniliprole | 200g/L SC | 20 g ai/ ha | helicoverpa |
| Avatar™ | Indoxacarb | 400g/ kg WG | 100 g ai/ ha | helicoverpa |
| SCSI-01 | Spirotetramat | 240 g/ L SC | 48 g ai/ha | Aphids |
| SCSI-03 | clothianidin | 200 g/ L SC | 5 g ai/ 100m row | Aphids |
| Mite-01 | Etoxazole | 110 g/ L SC | 38.5 g ai/ ha | Mites |
| Untreated | Nil | Nil | Nil | All pests |

At harvest, 25 cobs per plot were harvested from the middle two rows. The cobs were assessed for helicoverpa damage and marketability according to criteria listed in Table 21. Mite damage and infestation levels on the cobs were assessed according to the criteria in the Table 24.

**Table 24. Cob assessment criteria for mite infestation and product marketability**

| Mites infestation | Description | Marketability category |
|---|---|---|
| Nil infestation | No mites or very light discoloration on cobs | Fresh market (few mites removable in pack line washing) |
| Slight infestation | Up to 50 mites on outer husks and/ or some discoloration on outer husks | Pre-Packet Market - (cob may be used by removing outer husk leaves) |
| Heavy infestation | High infestation and severe discoloration on husk leaves | Unmarketable |

### c) Field Trial 3 – Materials & Methods

This trial was planted on 22 May 2007 to target the aphid and helicoverpa infestations during winter months. The insecticide treatments are summarised in Table 25. The insecticide sprays were applied at silking (on 2 Aug 07) using a motorised Knapsack sprayer fitted with two flat-fan nozzles (DG80015). The spray volume of 400 L/ha was used to cover both sides of the plant row.

Assessment: Trial plots were monitored at 7 to 10 day intervals for helicoverpa eggs and larvae, aphids, mites and beneficial insects. At harvest, 25 cobs per plot were harvested from the middle two rows. The cobs were assessed for helicoverpa damage and product marketability according to the criteria listed in Table 21.

Aphid infestation and contamination levels on the cobs were assessed according to the criteria in Table 10. For each plot, five cobs were randomly selected and outer husk leaves were removed for assessing aphid parasitism. Parasitised and healthy aphids were counted on the sampled leaves under a microscope.

**Table 25: Insecticide treatments applied in Trial 3 in 2007**

| Insecticides | Active ingredient | Formulations | Application rate ai g/ ha | Target pest |
|---|---|---|---|---|
| SCLI-01 | Flubendiamide | 480g/L SC | 48 g ai/ ha | helicoverpa |
| SCLI-02 | Chlorantraniliprole | 200g/L SC | 10 g ai/ ha | helicoverpa |
| SCSI-01 | Spirotetramat | 240 g/ L SC | 48 g ai/ha | Aphids |
| Chess™ | Pymetrozine | 500g/ kg WG | 100 g ai/ ha | Aphids |
| Primor™ | Pirimicarb | 500g/ kg WG | 325 g ai/ ha | Aphids |
| Untreated | Nil | | | All pests |

### d) Field Trial 4 – Materials & Methods

This trial was planted on 30 July 2007 to evaluate insecticide rotations for helicoverpa control. Three different insecticide rotation options were tested in larger plots (8 rows x 27m). The first insecticide sprays were applied at early silking (on 26 Sep 07) and the second sprays were applied 8 days later, using a tractor mounted boom-spray fitted with droppers. The spray volume of 650 L/ha was used. The treatments are summarised in Table 26.

Assessment: The first cob samples were collected on 10 Oct 07 and the second samples were collected on 18 Oct 07. At each sampling, 30 cobs per plot were harvested from the middle four rows. The cobs were assessed for helicoverpa damage and product marketability according to the criteria listed in Table 21.

**Table 26: Insecticide rotations applied for helicoverpa control in Trial 4 in 2007**

| **First spray** | Application rate (ai g/ ha) | **Second spray** | Application rate (ai g/ ha) |
|---|---|---|---|
| SCLI-02 | 20 g ai/ ha | SCLI-02 | 20 g ai/ ha |
| SCLI-01 | 48 g ai/ | Success II | 96 g ai/ ha |
| SCLI-02 | 20 g ai/ ha | Success II (spinosad 240 g/ L) | 96 g ai/ ha |

### 4.13 South Queensland - Soft Options Assessment – Materials & Methods

Three trials were planted on the Gatton Research Station - 25th January and harvested on the 18th April 2006 using Hi-brix (formally H5); 7th September and harvested on the 4th December 2006 using Golden Sweet; and 6th February 2007 using Hi-Brix; to evaluate a range of insecticides for lepidopteran insects and sap sucking insect control, and to monitor the effects of insecticides on naturally occurring beneficials.

The trial areas were 33m x 90m block consisting of 4 strips of 8 rows of sweet corn with a bare strip between each to allow the tractor mounted sprayer access to apply the individual treatments. The trial assessed sap sucking insect pests such as thrips and jassids in the early growth phases, aphids close to harvest, and the range of lepidopteran pests such as helicoverpa, sorghum head caterpillar and yellow peach moth from silking through to harvest. Additional agronomic practices, such as fertiliser application and weed management, were carried out by the research station farm staff.

#### a) Trial 1 – Materials & Methods

Hi-brix (formally H5) sweet corn variety was planted on the Gatton Research Station on the 25th January and harvested on the 18th April 2006 to evaluate a range of insecticides for lepidopteran insects and sap sucking insect control. The trial area covered approximately 33m x 90m block consisting of 4 strips of 8 rows of sweet corn with a bare strip between each to allow the tractor mounted sprayer access to apply the individual treatments. Individual plots were 6m (8 rows) x 11m. The trial looked at sap sucking insect pests such as thrips and jassids early and then aphids close to harvest, and the range of lepidopteran pests such as helicoverpa, sorghum head caterpillar and yellow peach moth from silking through to harvest. This trial was overhead irrigated for the first few weeks and then flood irrigated until harvest. Additional agronomic practices, such as fertiliser application and weed management, were carried out by the research station farm staff.

*Treatments*

Against sap sucking pests

SCSI-03a (500g ai) soil application 10g/100m row
SCSI-01 200ml/ha plus Hasten at 2ml/L
Dimethoate™ 800ml/ha plus Agral
These insecticides would only be used when monitoring indicated a need for application.

Against caterpillar pests

Avatar™ 170g/ha plus Agral
SCLI-03 200ml/ha plus Agral
SCLI-02 100ml/ha no Agral
SCLI-02 200ml/ha no Agral
SCLI-01 100ml/ha plus Agral
SCLI-01 150ml/ha plus Agral
Unsprayed control

These insecticides would be applied from the start of silking with a maximum of 3 sprays per treatment about a week apart. If aphids were thought to be a problem then the SCSI-01 product would also be evaluated.

*Trial design*

This trial had four replications of either 4 treatments for early sap sucking pests or 7 treatments from silking to harvest for caterpillar pests as well as aphids in a randomised block design. Each plot was

8 rows wide and 11m long. The outside row was a buffer with assessments taken from the inner 6 rows when monitoring and the inner 2 rows at harvest.

*Monitoring*

Monitoring was carried out weekly to check for thrips and jassids early and for caterpillar pests during silking. Two plants at 5 locations in each plot were monitored by inspecting the whole plant when they were small for thrips and jassids, while during silking, only the silks, cobs and nearby stalks were checked for eggs and larval presence. At harvest 10 cobs per plot were collected and assessed for signs of damage and grubs (helicoverpa, sorghum head caterpillars or yellow peach moth). Additional thrips counts were taken 34 days after planting (DAP) to assess the effectiveness of the soil applied insecticide SCSI-03a. The process involved removing 10 plants per plot and placing them into plastic bags and taking them back to the laboratory and systematically removing leaves counting both adults and nymphs. This was carried out for SCSI-03a and the control plots only. Plants were given a rating from 0-5 with respect to the damage on the leaves as seen in Photo 1 where 0=no damage and 5=severe damage.


Photo 1. Thrips damage to leaves of young sweet corn.

Aphid populations were assessed soon after harvest using a rating scale on the number of aphids found on the leaves in the treatments SCSI-01, SCLI-03, SCSI-03a and the unsprayed control plots only. Ten plants per plot were assessed using the following rating scale;

0 = 0-5 aphids
1 = 5-10 aphids
2 = 10-50 aphids
3 = 50-100 aphids
4 = 100-500 aphids
5 = greater than 500 aphids

Yellow sticky traps (YST) were also used to help in the assessment of beneficial insect activity within the individual plots. YST were placed out during silking every week for 24 hours and checked for insect pests and beneficials. The YST were only left in the field for 24 hours so as not to deplete the field populations over time and were placed at cob height.

*Equipment*

All foliar treatments were applied using a tractor mounted air assisted boom sprayer which was raised above the top of the sweet corn canopy putting on the equivalent of 600L/ha of water using Hardi 1553.21 cone nozzles with a number 2 swirl plate.

The SCSI-03a product was applied by hand into furrows with the seed planted into the furrow and covered over with soil.

### b) Trial 2 – Materials & Methods

Golden sweet variety of sweet corn was planted on the Gatton Research Station on the 7th September and harvested on the 4th December 2006 to evaluate a range of insecticides for lepidopteran insects and sap sucking insect pest control. The trial area covered approximately 33m x 90m block consisting of 4 strips of 8 rows of sweet corn with a bare strip between each to allow the tractor mounted sprayer access to apply the individual treatments. Individual plots were 6m (8 rows) x 10m. The trial looked at sap sucking insect pests such as thrips and jassids early and the lepidopteran insect pest, helicoverpa, from silking through to harvest. This trial was overhead irrigated for the first few weeks and then flood irrigated until harvest. Additional agronomic practices, such as fertiliser application and weed management, were carried out by the research station farm staff.

*Treatments*

<u>Against sap sucking pests</u>
SCSI-03 (200g ai) soil application 25ml/100m row
Confidor Guard™ soil application 14ml/100m row

<u>Against caterpillar pests</u>
Avatar™ 170g/ha plus Agral
SCLI-03 200ml/ha plus Agral
SCLI-02 50ml/ha plus 25ml/100L Agral
SCLI-02 100ml/ha plus 25ml/100L Agral
SCLI-01 100ml/ha plus Agral
SCLI-01 150ml/ha plus Agral
Unsprayed control
These insecticides would be applied from the start of silking with a maximum of 3 sprays per treatment about a week apart.

*Trial design*

This trial consisted of a randomised block design with four replications. The outside row was a buffer with assessments taken from the inner 6 rows when monitoring and the inner 2 rows at harvest.

*Monitoring*

Monitoring was carried out weekly to check for thrips and jassids early and for caterpillar pests during silking. Two plants at 5 locations in each plot were monitored by inspecting the whole plant when they were small for jassids, while at the same time 10 plants were removed from the control plots, SCSI-03 and Confidor Guard™ plots only for counting thrips back in the laboratory. These plants were cut off at the base and placed into plastic bags. Individual plants were assessed by removing the leaves and counting the thrips present both adults and nymphs. During silking only the silks, cobs and nearby stalks were checked for eggs and larval presence as well as beneficial insects. Two plants at 5 locations were monitored in each plot. At harvest 25 cobs per plot were collected and assessed for signs of damage and grubs (helicoverpa, sorghum head caterpillars or yellow peach moth). Additional thrips counts were also taken at this time for the control, SCSI-03 and Confidor Guard™ plots by removing the cob wrapper leaves and counting the number of thrips on these leaves.

Yellow sticky traps (YST) were also used to help in the assessment of beneficial insect activity within the individual plots. YST were placed out during silking every week for 24 hours and checked for insect pests and beneficials. The YST were only left in the field for 24 hours so as not to deplete the field populations over time and were placed at cob height.

*Equipment*

All foliar treatments were applied using a tractor mounted air assisted boom sprayer which was raised above the top of the sweet corn canopy putting on the equivalent of 500L/ha of water using Hardi 1553.21 cone nozzles with a number 2 swirl plate.

SCSI-03 and Confidor Guard™ were applied prior to planting using a cone planter fitted with spray lines just behind to planting shoes delivering the equivalent of 2.4L/100m of row and approximately 5cm below the ground. The crop was them planted using a Monosan air seeder.

### c) Trial 3 – Materials & Methods

Sweet corn (Hi-Brix) was planted on the Gatton Research Station on 6th February 2007 using an air seeder. This trial was overhead irrigated for the first few weeks and then flood irrigated until harvest. Additional agronomic practices, such as fertiliser application and weed management, were carried out by the research station farm staff.

The trial had four replications of 8 treatments in a randomised complete block design (32 plots total). Each plot was 8 rows wide and 11 m long.

Four soil applied chemicals and three foliar applied chemicals were assessed, compared with an untreated control (Table 4). All soil treatments were applied at the equivalent rate of 2.61 L of solution per 100 m of row, and were applied just prior to planting.

Table 27. Treatments

| Treatment | Application rate | Application type and dates |
|---|---|---|
| Unsprayed control | N/A | N/A |
| Actara™ | 10 g/100 m row | Soil application (at sowing 6th Feb) |
| Confidor Guard™ (350g ai) | 14 ml/100 m row | Soil application (at sowing 6th Feb) |
| SCSI-02 Soil | 100 g ai/ha | Soil application (at sowing 6th Feb) |
| SCSI-03b (200g ai) | 25 ml/100 m row | Soil application (at sowing 6th Feb) |
| Dimethoate™ | 800 ml/ha + Agral™ | Foliar application (5th April) |
| SCSI-01 | 200 ml/ha +Hasten™ at 2 ml/L | Foliar applications (5th, 13th & 23rd April) |
| SCSI-02 Foliar | 750 ml/ha +Hasten™ at 5 ml/L | Foliar applications (5th, 13th & 23rd April) |

*Equipment*

The soil applied treatments were applied prior to planting using a cone planter fitted with spray lines just behind the planting shoes delivering the equivalent of 2.61L/100m of row and approximately 5cm below the ground. The crop was then planted using a Monosan air seeder.

All foliar treatments were applied using a tractor mounted air assisted boom sprayer which was raised above the top of the sweet corn canopy putting on the equivalent of 600L/ha of water using Hardi 1553.21 cone nozzles with a number 2 swirl plate.

Table 28.  Trial schedule

| Date | DAS * | Activity |
|---|---|---|
| 06/02/07 | 0 | Sowing<br>Application of soil applied chemicals |
| 19/02/07 | 13 | Assessment (soil applied treatments) for thrips, aphids, jassids, leafhoppers |
| 26/02/07 | 20 | Assessment (soil applied treatments) for thrips, aphids, jassids, leafhoppers |
| 05/03/07 | 27 | Assessment (soil applied treatments) for thrips, aphids, jassids, leafhoppers |
| 12/03/07 | 34 | Assessment (soil applied treatments) for thrips, aphids, jassids, leafhoppers |
| 04/04/07 | 57 | Assessment (all treatments) |
| 05/04/07 | 58 | Foliar application (vegetative stage) |
| 12/04/07 | 65 | Assessment (all treatments) |
| 13/04/07 | 66 | Foliar application (silking stage) |
| 18/04/07 | 71 | Assessment (all treatments) |
| 23/04/07 | 76 | Foliar application (silking stage) |
| 26/04/07 | 79 | Assessment (all treatments) |
| 30/04/07 | 83 | Harvest assessment |

* DAS = days after sowing

*Monitoring*

Weekly monitoring was performed to assess numbers of sap sucking pests (thrips, jassids, aphids, leafhoppers) early in the crop, then numbers of helicoverpa and other pests (aphids, mites, flea beetles, sorghum head caterpillar) from silking until harvest.  A final assessment of lepidopteran pests, cob damage, aphids and thrips was performed at harvest when 10 cobs per plot were collected and assessed in the laboratory.  Thrips numbers were assessed by removing the cob wrapper leaves and counting the numbers of thrips on these leaves.

At each weekly assessment, ten plants per plot were inspected and the numbers of insects on each recorded.  Thrips were monitored by removing 10 plants per plot, placing them into plastic bags and examining them in the laboratory.  Individual plants were assessed by removing the leaves and counting the thrips present both adults and nymphs.   Mites were assessed according to a rating scale, based on the size of the mite infestation:

1 = small area infested

2 = 2 leaves infested

3 = 3 or more leaves infested

For all other pests, actual insect numbers were counted.

Numbers of beneficial insects were also recorded throughout the trial.

Yellow sticky traps (10 x 12 cm) were used as an additional method of monitoring for pests beneficial insect activity within the individual plots.  The traps were placed at cob height left in the field for 24 hours at approximately weekly intervals from 57 DAS until harvest.

*Statistical Analysis*

Where insect numbers were sufficient to allow statistical analysis, data were subjected to analysis of variance (ANOVA), followed by least significant different (LSD) tests to distinguish between treatment means.  Prior to analysis, data were checked to ensure they met the assumptions of the statistical model, and transformed where necessary (log10 or square root transformation).  Data were back transformed for presentation.  All analyses were performed using the GenStat™ 9th edition program.

## 4.20 Monitoring Pests and Beneficial Organisms – Materials & Methods

**Naturally Occurring Beneficial Arthropods** are an important component of IPM systems. A large range of beneficials which contribute towards the management of Helicoverpa and other pests of sweet corn have been identified through the previous project (VG97036). The Monitoring of Pests and beneficials activity has been reported in detail in Milestone Report #4 - Pests and Beneficial Insects and Arthropods in Sweet Corn (30th May 2007) and in Appendix 3.

A number of narrow spectrum ("soft option") insecticides have been made available to the project team through three chemical companies, Bayer CropScience, DuPont Australia and Sumitomo Chemicals – each product has been allocated a project code, as not all of these soft options products are registered in Australia (see Table below).

| Chemical Company | Company Code | Active Ingredient | Trade Name | Project Code |
|---|---|---|---|---|
| Bayer | NNI0001 | flubendiamide | Belt 480 SC | SCLI-01 |
| | BYI8330 | spirotetramat | Movento 240SC | SCSI-01 |
| DuPont | DPX-E2Y45 SC | chlorantraniliprole | Coragen SC | SCLI-02 |
| | DPX-HGW86 | | Soyate 100 SC | SCSI-02 |
| Sumitomo | S-1812 | pyridalyl | Symphony 500 EC | SCLI-03 |
| | TI-435 | clothianidin 200SC | | SCSI-03 |
| | TI-435 | clothianidin 500WG | | |
| | | etoxazole | Paramite 110 SC | Mite-01 |

The project work program has concentrated on the assessment of new "soft options" as additional components of Integrated Pest Management, and assessing the effects of these soft options on naturally occurring beneficial organisms which have the potential to contribute to sweet corn IPM systems.

**Beneficial insects in sweet corn**

Not all the insects and other arthropods we see in sweet corn are doing damage to the crop. Many are in fact beneficials, or 'natural enemies' of the real pests. It is important to be able to recognise friend from foe, and take the appropriate steps to make the best use of these beneficials.

Not all natural enemies are insects. Other non-insect arthropods that help control pests in your crop are spiders and predatory mites. Avoiding the use of broad spectrum or highly toxic pesticides, using biological pesticides such as *Bacillus thuringiensis* (Bt) or helicoverpa nucleopolyhedorvirus (NPV), changing pesticide application methods (e.g. soil injection) and introducing natural enemies into the crop all increase natural enemy activity.

**Parasitoids** are organisms that parasitise and kill their hosts. The adults are free-living and are usually wasps or flies. The adult lays its eggs within or on the host pest at a critical like stage. The immature stage develops on or within an insect host, completing their entire development within that host by consuming it and eventually killing the host. Parasitoids tend to be very specific to their host, there are various wasp parasitoids that attack moth eggs, aphids or caterpillars.

Egg parasitoids, such as *Trichogramma* spp. and *Telenomus* spp. may attack and develop in a range of moth eggs, typically turning the egg a silvery black. In comparison parasitised caterpillars show few external signs of parasitism before dying. The parasitoid larvae can sometimes be seen if the parasitised caterpillar is carefully pulled apart. Larval parasitoids include *Heteropelma* and several smaller Braconid wasps, *Cotesia*, *Microplitis* and tachinid flies.

Aphids are often parasitised and are noticeable as bloated buff or brown/ black shells commonly called 'mummies'. The aphid parasitoid, a small wasp, emerges through a circular hole in the abdomen of the aphid shell.

To determine the level of parasitoids in your crop you need to collect and rear the pests to observe if parasitoids will emerge from their host. Emergence could take from one to 50 days.

Apart from protecting existing parasites in your crop by using chemicals that will not harm beneficials, a limited number of parasitoids are mass reared by commercial producers. The most common is the egg parasitoid *Trichogramma pretiosum* which has a wide host range.

**Predators** feed directly on their prey. They include insects such as predatory beetles, ants, lacewings, predatory bugs, predatory mites and spiders. Most predators are generalists, attacking a wide range of insects such as aphids, thrips, moth eggs, and small, medium and large grubs. Predators generally attack insects that are smaller than themselves.

Predators also supplement their diet with nectar, pollen and fungi. In most cases it is the larvae of these predators that are the main feeders and they tend to feed on the slower moving sap suckers including aphids, whiteflies and mites. Table 29 shows the relationships between natural enemies and pests found in sweet corn.

Table 29. Relationships between natural enemies and primary and secondary insect pests found in sweet corn.

| | **Beneficials (natural enemies)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Parasitoids*** | | | | | | | ***Predators*** | | | |
| **Pest** | **Trichogramma** | **Telenomus** | **Microplitis** | **Heteropelma** | **Cotesia** | **Tachinid fly** | **Aphid parasitoid** | **Lacewings** | **Ladybirds** | **Predatory bugs** | **Spiders** |
| helicoverpa eggs | ✓ | ✓ | | | | | | | ✓ | ✓ | ✓ |
| helicoverpa larvae | | | ✓ | ✓ | ✓ | ✓ | | | small | ✓ | ✓ |
| Armyworm | | | | | ✓ | | | | | ✓ | |
| Sorghum head caterpillar | | | | | ✓ | | | | | ✓ | ✓ |
| Yellow peach moth | ✓ | | | | | | | | ✓ | | ✓ |
| Aphids | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Thrips | | | | | | | | | some | ✓ | ✓ |

✓ indicates host or prey of natural enemy

Queensland Department of Primary Industries and Fisheries, New South Wales Department of Primary Industries (NSW DPI) and the Department of Agriculture and Food Western Australia have been involved in helping further improve the IPM strategies developed as part of the sweet corn project VG97036 “Insect pest management in sweet corn” (1997-2001). During the course of this research, since early 2006 a number of commercial sweet corn fields in QLD, NSW and WA have been scouted for insect pests and beneficials.

## 4.21 New South Wales - Monitoring Pests and Beneficial Organisms – Materials & Methods

### a) Additional 2007 non-replicated Trial

A small block of Jubilee sweet corn was planted specifically for this trial on the 12th December at Yanco Agricultural Institute, Yanco, Riverina, NSW and harvested on the 1st March 2007.

Twenty plants in each plot were monitored in the field weekly except for in week four when the harvest assessment was conducted. Four groups of five plants were randomly chosen for monitoring. Each plant was monitored for pest and beneficial insects. Each plant was inspected from soil level to the tip, excluding tillers; only the main stem was inspected from top to bottom. Sticky traps were present in each plot and replaced weekly. helicoverpa eggs (excluding the freshly laid eggs) were collected and observed for parasitism in the lab. Harvest assessment was conducted during week four, sticky traps were not collected during this week and no field monitoring was conducted. Insect counts for week four were obtained from the harvest assessment where sixty cobs per treatment were harvested into bags and transferred to the lab for assessment. All insects found in the bag and on the cobs were recorded for each treatment.

### b) 2007-08 Trials

Two trials were conducted during the 2007/08 season at the Yanco Agricultural Institute, NSW, to assess the efficacy of different spray programmes that were based either on new generation, narrow spectrum chemicals or older broad spectrum chemicals for controlling helicoverpa (*Helicoverpa armigera*).

The first scouting involved checking five random plants per plot in Trial 1 (i.e. 20 plants per treatment) and ten random plants per plot in Trial 2 (i.e. 40 plants per treatment). These assessments involved checking for helicoverpa eggs and larvae. Subsequent scouting for helicoverpa involved checking ten random plants per plot in both blocks. The final two scouting assessments involved checking ten random plants per plot (i.e. 40 plants per treatment) in both blocks for all pests and beneficial insects.

Beneficial insects were recorded into the following groups :-

Table 30 : Beneficial arthropods groups recorded for both trials

| Beneficial groups | Beneficial species |
|---|---|
| Ladybird beetles | Includes the Transverse, White collared and Minute ladybird beetles. |
| Other beetles | Includes the Pollen, Rove and Flower beetles. |
| Lacewings | Includes the Green and Brown lacewings |
| Predatory bugs | Includes the Minute, Bigeyed and Damsel bugs |
| Spiders | Various species were present. |

Note: Flower beetles are not considered a beneficial but have been included when monitoring.

## 4.22 Western Australia - Monitoring Pests and Beneficial Organisms – Materials & Methods

From 23 November 2005 to 31 January 2007, monitoring was conducted once per week by the Department of Agriculture and Food WA at Wanneroo, approximately 25 km north of Perth. Additional information was obtained from a commercial IPM company (Manchil IPM) monitoring the same Wanneroo property (2007/08) and another commercial farm at Baldivis (2006/07). At both sites, sweet corn was grown on sandy soils on the Swan Coastal plain and irrigated by overhead irrigation.

60 plants were randomly selected within a bay at each weekly visit for detailed monitoring. The stage of the crop (seedling, vegetative, tasselling, silking) was recorded. At the seedling and vegetative stages, the entire plant was examined for pests and beneficials and the presence of parasitised helicoverpa eggs. During silking and tasselling, the silk, flag leaves, tassels and developing cob were examined for pests and beneficials, in particular for helicoverpa eggs and larvae. Helicoverpa presence was recorded as white eggs, brown eggs, very small larvae (0-3 mm), small larvae (3-10 mm), medium larvae (10-23 mm) and large larvae (>23 mm). Action was recommended to the grower if the number of helicoverpa eggs or larvae exceeded that recommended by QDPI.

For monitoring by Manchil IPM, plants were examined once per week, with the percentage of plants infested with pests or inhabited by beneficials (lacewings, ladybirds) being recorded, including the percentage of eggs parasitised by trichogramma and the size and location of helicoverpa larvae e.g. in flowers, in silk. The percentage of pest damage (damage by caterpillars) was also estimated.

## 4.23 North Queensland - Monitoring Pests and Beneficial Organisms – Materials & Methods

Four field trials were established during the 2006 and 2007 cropping seasons in Bowen, to evaluate a number of narrow spectrum insecticides and miticides against helicoverpa, aphids and mites.

The trials were conducted on the DPI&F Research Station, Bowen, Queensland from May to November to expose the crop to various pest pressures. Each trial area consisted of 16 rows with 80m long at 75 cm row spacing. All experimental plots were grown with the trickle irrigation system and irrigated at weekly intervals until final harvest.

The sweet corn variety Golden Sweet was directly seeded in all four trials. Insecticide treatments were arranged in a randomised complete block design with three replicates.

### a) Field Trial 1 – Materials & Methods

Trial plots were monitored at 10 to 14 days intervals for beneficial insects.

### b) Field Trial 2 – Materials & Methods

Trial plots were monitored at 7 to 10 days intervals for beneficial insects. Three weeks after treatment application, 10 leaves per plot were collected to assess mite levels and predator densities. Leaf samples were taken to the laboratory where 3 x 1cm$^2$ areas were selected on each leaf and all mite stages and *Stethorus* (mite-eating ladybird larvae) were counted under microscope.

### c) Field Trial 3 – Materials & Methods

Trial plots were monitored at 7 to 10 days intervals for beneficial insects.

Aphid infestation and contamination levels on the cobs were assessed. For each plot, five cobs were randomly selected and outer husk leaves were removed for assessing aphid parasitism. Parasitised and healthy aphids were counted on the sampled leaves under microscope.

## 4.24 South Queensland - Monitoring Pests and Beneficial Organisms – Materials & Methods

Three trials were carried out in south east Queensland to investigate the effectiveness of a number of insecticides for the control of secondary insects pests, including thrips and aphids. At the same time, their effectiveness against helicoverpa and their effect against the beneficial insect populations during the growing season were also assessed.

### a) & b) Trials 1 & 2 – Materials & Methods

For Trials 1&2, yellow sticky traps (10 x 12 cm) were used as an additional method of monitoring for pests beneficial insect activity within the individual plots. YST were placed out during silking every week for 24 hours and checked for insect pests and beneficials. The YST were only left in the field for 24 hours so as not to deplete the field populations over time and were placed at cob height.

### c) Trial 2 – Materials & Methods

For Trial 3, traps were placed at cob height and left in the field for 24 hours at approximately weekly intervals from 57 DAS until harvest. Plants were inspected at weekly intervals and at harvest, and numbers of insect pests and beneficials recorded.

## 4.30 Disease Management – Materials & Methods.

**A survey of growers in the major production districts through Queensland, New South Wales, Victoria, Western Australia and Tasmania was conducted** principally to determine the range of sweet corn diseases encountered and their severity. The survey was conducted by face to face interviews, telephone interviews and in a few instances by initial telephone contact and facsimile for data collection.

While the major focus of the survey was to gather information on sweet corn diseases, the opportunity was taken to update information on secondary pests and the longer term impact of the previous project, *Insect Pest management in Sweet Corn,* VG 97036. A common questionnaire was used to structure interviews. Data was collected on diseases, pests and measures used to manage them; sources of information; crop management factors and additional skills and knowledge required; and the most desirable method of delivering information from this project to industry members.

There are a number of diseases which limit yield potential in sweet corn, and the disease tolerance status of a range of cultivars is available from seed companies and grower experience. Current information on the occurrence and frequency of diseases in the sweet corn industry has been collected and collated.

### 4.31 Australian Disease Survey

A survey of growers in the major production districts through Queensland, New South Wales, Victoria, Western Australia and Tasmania was conducted principally to determine the range of sweet corn diseases encountered and their severity. The survey was conducted by face to face interviews, telephone interviews and in a few instances by initial telephone contact and facsimile for data collection.

### 4.32 North Queensland - Disease Management – Materials & Methods

A disease severity trial using 27 varieties was planted at the Bowen Research Station on 17$^{th}$ August 2007, in a Randomized Complete Blocks Design of 27 treatments and 2 Replications. Each plot was 5m long consisting of a double row of sweet corn, with a 1m passageway in between each plot.

Table 31: Varieties Screened for Diseases.

| Line# | Company | Variety | Line# | Company | Variety |
|---|---|---|---|---|---|
| 1 | DPI&F | TSS1 | 14 | Lefroy Valley | HY 1790 OL |
| 2 | DPI&F | TSS2 | 15 | Lefroy Valley | HY 1481 OM |
| 3 | DPI&F | TSS3 | 16 | Lefroy Valley | HY 1516 OM |
| 4 | DPI&F | TSS4 | 17 | Lefroy Valley | HB 2630 OM |
| 5 | DPI&F | TSS5 | 18 | Jarit | Crackerjack |
| 6 | DPI&F | TSS6 | 19 | Jarit | Firestar |
| 7 | Sunland | Sentinel | 20 | Jarit | JTS208 |
| 8 | Sunland | Max | 21 | Jarit | JTS209 |
| 9 | Sunland | Suregold | 22 | Jarit | JTS215 |
| 10 | Sunland | Polaris Bicolour | 23 | Jarit | JTS228 |
| 11 | Snowy River | Golden Sweet Improved | 24 | Syngenta | GSS 6352 |
| 12 | HSR | Lancaster | 25 | Syngenta | GSS 9372 |
| 13 | Lefroy Valley | HY 579 OK | 26 | Seminis | Obsession |
| | | | 27 | Seminis | Passion |

## 4.40 Toxicity of three "soft options" insecticides against a range of beneficials – Materials and Methods.

This research formed part of an Honours project by Jessica Harrison (Environmental Science, Curtin University). Together with funding from this project, Jessica also received a scholarship from the Cooperative Research Centre for National Plant Biosecurity.

A number of narrow spectrum insecticides have been made available to the project team through three chemical companies, Bayer CropScience, DuPont Australia and Sumitomo Chemicals – each product has been allocated a project code, as not all of these soft options products are registered in Australia (see Table below).

| Chemical Company | Company Code | Active Ingredient | Trade Name | Project Code |
|---|---|---|---|---|
| Bayer | NNI0001 | flubendiamide | Belt 480 SC | SCLI-01 |
| | BYI8330 | spirotetramat | Movento 240SC | SCSI-01 |
| DuPont | DPX-E2Y45 SC | chlorantraniliprole | Coragen 200 SC | SCLI-02 |
| | DPX-HGW86 | | Soyate 100 SC | SCSI-02 |
| Sumitomo | S-1812 | pyridalyl | Symphony 500 EC | SCLI-03 |
| | TI-435 | clothianidin 200SC | | SCSI-03 |
| | TI-435 | clothianidin 500WG | | |
| | | etoxazole | Paramite 110 SC | Mite-01 |

The aim of this study was to determine the effect of chlorantraniliprole, flubendiamide and spirotetramat on species representative of the Coccinellidae (*Coccinella transversalis* Fabricius) - Transverse ladybird; *Cryptolaemus montrouzieri* Mulsant)- Mealybug predator, Neuroptera (*Mallada signata* (Schneider)) - Green Lacewing and Chalcidoidea (*Trichogramma pretiosum* Riley) - Helicoverpa parasite.

With the exception of *C. montrouzieri*, all naturally occur in sweet corn in Australia and are effective biological control agents whose preservation is important in IPM. *T. pretiosum* is also released innundatively for the control of heliothis.

Selection of these species was also based on their suitability as test organisms with respect to their longevity in confinement; and they were commercially available from insectaries to ensure uniformity of age.

### Introduction

Reduced-risk or narrow spectrum insecticides have recently been developed for a range of horticultural pests. These insecticides may eventually replace older, broad spectrum insecticides such as carbamates and organophosphates (chemical classes 1A and 1B), which are increasingly being restricted or removed from use due to human health, environment and/or trade concerns in Australia (APVMA 2007a,b) and overseas (Stark and Banks 2001). Reduced risk insecticides represent new chemical classes with novel modes of action (IRAC 2008), and are regarded to be useful for resistance management, since pests that have developed resistance to other chemical classes have not been exposed to these insecticides. They are also narrow spectrum, with activity against a single order of insects (e.g. Lepidoptera, Coleoptera) or feeding group (e.g. sucking, chewing insects). They are also regarded to be safe to non-target organisms, and therefore suitable for use in integrated pest management (IPM) programs (Tohnishi *et al*. 2005; Warner *et al*. 2007). Three new insecticides chlorantraniliprole, flubendiamide and spirotetramat are being considered for use in sweet corn.

Chlorantraniliprole is likely to be marketed as Rynaxypr™ or Coragen™, and flubendiamide will be marketed worldwide as Belt™: both are representatives of diamides (chemical class 28). Diamides selectively activate the insect's ryanodine receptors, resulting in interruption of normal muscle contraction, eventually leading to paralysis and death. Chlorantraniliprole has activity against Lepidoptera including *Plutella xylostella* (diamondback moth), *Spodoptera frugiperda* (fall armyworm) and *Heliothis virescens* (tobacco budworm) (Clark *et al*. 2008; Knight & Flexner 2007; Lahm *et al.* 2005, 2007). Flubendiamide shows activity against a broad range of Lepidopteran pests particularly the larvae, including insecticide resistant strains (Lahm *et al*. 2005; Tohnishi *et al*. 2005; Ebbinghaus-Kintscher *et al*. 2006). In 2008, chlorantraniliprole was registered in Australia for the control of moth pests including helicoverpa in a range of vegetable crops, but not sweet corn. Flubendiamide is being considered for registration by the APVMA in Australia.

Spirotetramat is a tetramic acid insecticide (chemical class 23) that is being marketed world-wide as Movento™. Other novel insecticides in this class include spiromesifen (Oberon™) and spirodiclofen (Envidor™). These insecticides inhibit lipogenesis (the process by which simple sugars such as glucose are converted to fatty acids), resulting in decreased lipid content, growth inhibition of younger insects, and a reduction in the ability of adult insects to reproduce (United States Environmental Protection Agency, 2008). Spirotetramat is translocated within the plant and is reported to have "*2-way systemicity", which distributes the active ingredient upwards and downwards in the plant to find and eliminate even hidden pests wherever they live and feed*" (Bayer CropScience 2008). Spirotetramat has activity against a broad range of sap-sucking pests including aphids, whiteflies, scales and mealy bugs. Though not registered in Australia at present, all Spirotetramat, spirodiclofen and spiromesifen are registered in Canada, New Zealand, and the USA for control of sucking pests in a range of crops including vegetables.

The aim of this study was to determine the effect of chlorantraniliprole, flubendiamide and spirotetramat on species representative of the Coccinellidae (*Coccinella transversalis* Fabricius; *Cryptolaemus montrouzieri* Mulsant), Neuroptera (*Mallada signata* (Schneider)) and Chalcidoidea (*Trichogramma pretiosum* Riley). With the exception of *C. montrouzieri*, all naturally occur in sweet corn in Australia and are effective biological control agents whose preservation is important in IPM. *T. pretiosum* is also released inundatively for the control of helicoverpa. Selection of these species was also based on their suitability as test organisms with respect to their longevity in confinement; and they were commercially available from insectaries to ensure uniformity of age.

**Insecticides**

Insecticides and rates tested are listed in Table 32, and test species and test method are listed in Table 33. Deltamethrin was included as a positive control since it is registered for use in sweet corn and is known to be detrimental to beneficial insects such as trichogramma (Scholz and Zalucki 2000). Spinosad was also included as a control, since it is registered in sweet corn and is regarded to be IPM friendly (Scholtz and Zalucki 2000). Test solutions were prepared by diluting the insecticide with the appropriate volume of water.

**Table 32: Insecticide modes of action and application rates (gai $L^{-1}$)**

| Insecticide | Trade Name | Manufacturer | Mode of Action | Rate (gai $L^{-1}$) |
|---|---|---|---|---|
| Chlorantraniliprole | Rynaxypyr™ | Dupont | ryanodone receptor modulator | 0.03*<br>0.06<br>0.12 |
| Deltamethrin | various | various | sodium channel modulator | 0.01375*<br>0.0275<br>0.06875 |
| Flubendiamide | Belt™ | Bayer | ryanodone receptor modulator | 0.072*<br>0.144<br>0.36 |
| Spirotetramat | Movento™ | Dupont | lipid biosynthesis inhibitor | 1*<br>2<br>5 |
| Spinosad | Success™ | Dow AgroSciences | nicotinic acetylcholine & GABA receptors modulator | 0.048 *<br>0.096<br>0.24 |

* recommended rate

**Table 33: Insect species tested**

| Common name | Scientific name | Test stage | Test method | Measurements |
|---|---|---|---|---|
| Mealy bug predator | *Cryptolaemus montrouzieri* | adult | Residue (filter paper, corn plant) | Mortality |
| Transverse ladybird | *Coccinella transversalis* | adult | Residue (filter paper) | Mortality |
| Green lacewing | *Mallada signata* | larva (Instar 1, 2) | Residue (filter paper, corn plant) | Mortality<br>Pupation<br>Adult emergence |
| helicoverpa parasite | *Trichogramma pretiosum* | pupa | Spraying on pupa | Mortality |

## Acute Toxicity Bioassays

Studies were conducted at the Department of Agriculture and Food (WA) in South Perth. Parasitized host eggs of *Trichogramma pretiosum*, adult *Cryptolaemus montrouzieri* and first instar *Mallada signata*, were sourced from a commercial insectary (Bugs for Bugs, Mundubbera, Queensland). *C. transversalis* adults were collected from the field. Initial toxicity assays were conducted using three rates of the new insecticides (field rate, 3X field rate and 5X field rate) for *C. montrouzieri* and *M. signata* to assess mortality rate, and *T. pretiosum* to assess successful eclosion, relative to the control group (water only). All bioassays were carried out in a controlled temperature cabinet (25 ± 1°, 60 ± 10% RH; 16L:8D photoperiod).

### Ladybirds and lacewings

Cup-shaped filter papers (18 cm in diameter) were dipped into the test solutions for ten seconds, then fitted into plastic cups (70mm wide, 60mm high, 52mm base; Genfac Plastics) with ventilated lids to ensure that test insects were not fumigated. The filter paper lined the plastic cups, ensuring maximum exposure of the treated surface to the test insects. Fifteen adult *C. montrouzieri* or ten first instar *M. signata* was released into the plastic cup. Treatments were arranged in a randomised complete block design with five replicates per treatment.

Ladybirds were fed on a diet of honey-water solution, whilst *M. signata* were fed live aphids (*Rhopalosiphum maidis* and *Myzus persicae*), replenished on alternate days for the duration of the experiment. Mortality was assessed 96 hours after commencement of the trial, with the criterion for death failure to move when stimulated with a fine brush. Insects with abnormal symptoms such as body contraction or paralysis were monitored for possible recovery, before being included in the number of dead.

A second series of assays were conducted using the recommended rates of the new insecticides to assess adult mortality for *C. transversalis* and to assess pupation of *M. signata*. Positive controls (deltamethrin and spinosad for *C. transversalis*, spinosad for *M. signata*) were also included. Filter paper discs were dipped into insecticide solutions for ten seconds (or water for the control), then placed in petri dishes for lacewings (70 x 10 mm) or into plastic cups (70mm wide, 60mm high, 52mm base; Genfac Plastics) for *C. transversalis*. Five adult *C. transversalis* or a single *M. signata* larva were then released into each 'cage'. *C. transversalis* were fed on a diet of honey-water solution and *Sitotroga* eggs, replenished daily for the duration of the experiment. Mortality was assessed 96 hours after commencement of the trial, with death defined by failure to move when stimulated with a fine brush. Ladybirds with abnormal symptoms such as body contractions or paralysis were monitored for possible recovery, before being included in the number of dead. *M. signata* were fed live aphids (*Rhopalosiphum maidis* and *Myzus persicae*) and sterilized *Sitotroga* eggs, replenished daily. Larvae were checked daily until they pupated, then checked daily until adults emerged. The date that larvae pupated and the date that they emerged was recorded. In each experiment, treatments were arranged in a randomised complete block design with seven replicates per treatment.

**Figure 1: Cage design for acute toxicity bioassays. Cup-shaped filter papers were fitted into plastic cups (left) with ventilated lids (right).**

Trichogramma

The eggs of the Angoumois grain moth (*Sitotroga cerealella* Olivier) were the factitious host used for rearing *Trichogramma pretiosum*. Approximately fifty eggs of *S. cerealella* enclosing the parasitoid pupae were exposed to insecticidal solutions, by placing the eggs on filter paper discs dipped in solution for ten seconds and then placing them in petri dishes (70 x 10 mm). The assessment of toxicity of insecticides on the immature pupal stage (168-192 hours) was based on successful eclosion of adult *T. pretiosum.* Eclosion was assessed after adult parasitoids had been allowed enough time to emerge (144 hours) and was determined by counting the number of black eggs (which indicates parasitism) without emergence openings, or where the parasitoid had opened an emergence hole in the host chorion, yet was still inside the host egg.

**Semi-Field Trial**

Four corn seedlings were planted into black plastic pots (20 cm diameter) containing Baileys potting mix (Baileys Fertilisers, Rockingham, Western Australia). Plants were fertilised weekly with a granular fertiliser containing nitrogen, phosphorus, potassium and trace elements (Soluble All Purpose Thrive, Yates Australia). Seedlings were grown in a glasshouse for four weeks; until they reached an average height of 60 cm. Plants were then located outdoors, under partial cover to prevent rain from diluting residues and exposure to harsh sunlight. Plants were sprayed with a two-litre hand-pump aerosol polypropylene spray bottle till runoff at the recommended field rate. Control groups were treated with tap water. Plants were then allowed to dry before the test species (10 individuals per replicate) were introduced to the cages. Treatments were arranged in a randomised complete block design with five replicates per treatment, except for deltamethrin (one replicate).

Cages were composed of a pair of wire frames sunk into the soil (approx. 40cm high; figure 2), covered with fine-mesh bags (70 x 40 cm). Plants were bent to fit the cage. The bags were secured by elastic around the rim of the pot and with plastic clips at the top to prevent insects escaping. *C. montrouzieri* were fed on a diet of honey-water solution, whilst *M. signata* were fed on a diet of *Rhopalosiphum maidis* and sterilized moth eggs (*Sitotroga* eggs; sourced from Bugs for Bugs) replenished on alternate days for the duration of the experiment. The pots were watered on alternate days, ensuring that only the soil was moistened to avoid insecticidal residues being washed off.

**Figure 2: Cage design for semi-field trial**

***Statistical Analysis***

Percentage survival rates and developmental times (days) for all stages were analysed using GENSTAT software (11th edition). Mortality and eclosion rates of the test species were analysed using an analysis of variance, with the data transformed where necessary using an arcsine or log for reciprocal transformation to stabilise variances prior to analysis. The LSD mean separation test was used to compare means within significant ANOVAs ($p < 0.05$).

The results of the insecticidal treatments were compared with those of the water treated control and the positive control (deltamethrin). Based on results (mortality, eclosion), insecticides were classified into four evaluation categories according to the degree of harm that they cause the test species (Sterk et al., 1999):

1 = harmless (<30%),

2 = slightly harmful (30-79%),

3 = moderately harmful (80-99%) and

4 = harmful (>99%)

## Disclaimer:

***A range of insecticides are referred to in this report. Where an insecticide is named together with ™ as a superscript, this refers to the insecticides' Registered Trade Name. This DOES NOT imply that this insecticide is registered for use on sweet corn in Australia. It is important that the registration status of all insecticides are verified prior to their application to sweet corn in Australia.***

# 5.00 Results

## 5.10 Soft Options Assessment - Results.

The results of the work program have demonstrated that **four (4) 'soft options' insecticides and one (1) miticide have potential, for the management of insect and mite pests in the Australian sweet corn industry**. These are Movento™ and SCSI-03, which are effective against sucking insects (thrips and aphids); Belt™ and Coragen™, which are very effective against Helicoverpa and Sorghum Head Caterpillar, and Paramite™, which suppresses 2-spotted mite populations.

Additionally, these new pesticides appear to have low impacts on beneficial insects.

A number of narrow spectrum insecticides have been made available to the project team through three chemical companies, Bayer CropScience, DuPont Australia and Sumitomo Chemicals – each product has been allocated a project code, as not all of these soft options products are registered in Australia (see Table below).

| Chemical Company | Company Code | Active Ingredient | Trade Name | Project Code |
|---|---|---|---|---|
| Bayer | NNI0001 | flubendiamide | Belt 480 SC | SCLI-01 |
| | BYI8330 | spirotetramat | Movento 240SC | SCSI-01 |
| DuPont | DPX-E2Y45 SC | chlorantraniliprole | Coragen | SCLI-02 |
| | DPX-HGW86 | | Soyate SC | SCSI-02 |
| Sumitomo | S-1812 | pyridalyl | Symphony | SCLI-03 |
| | TI-435 | clothianidin 200SC | | SCSI-03 |
| | TI-435 | clothianidin 500WG | | |
| | | etoxazole | Paramite | Mite-01 |

### 5.11 New South Wales – Soft Options - Results

**a) 2005-06 Trials**

Helicoverpa pressure was relatively high at the beginning of both trials. At the initial assessment for the Yanco trial there were 8 eggs and 146 larvae found on 320 plants (32 plots x 10 plants). This gives an average of 1 egg per 40 plants and 1 larva per 2.34 plants. At the initial assessment for the Whitton trial there were much higher egg numbers with 66 eggs found on the 32 plots (an average of 1 egg per 4.85 plants). Larvae numbers were about 35% higher than on Yanco trial with 197 found on the 32 plots (an average of 1 larva per 1.62 plants).

Yanco trial

The Yanco trial was harvested on 13th February 2006. Fifty random samples were collected from each plot and assessed for grub damage. Table 34 contains the harvest results. Numbers in the same column sharing a common letter are not significantly different by Tukey's test at P = 0.05

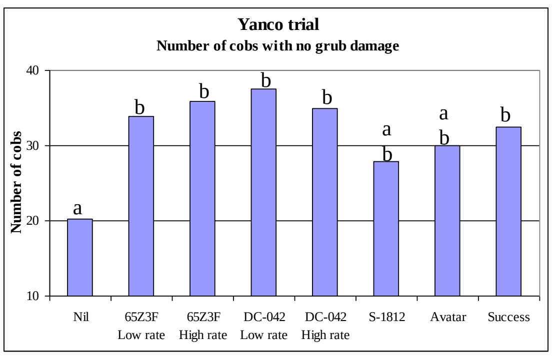
Table 34: Harvest results for Yanco trial

| Treatment | Nil Dam | Tip Dam | Side Dam | Tot Dam | Grub # |
|---|---|---|---|---|---|
| Nil | 20.25a | 26.25 b | 3.50a | 29.75 b | 6.25 b |
| SCLI-01 (Low rate) [=65Z3F] | 33.90 b | 15.60ab | 0.50a | 16.10ab | 4.55ab |
| SCLI-01 (High rate) [=65Z3F] | 35.88 b | 13.63a | 0.50a | 14.13a | 2.28ab |
| SCLI-02 (Low rate) [=DC-042] | 37.50 b | 12.25a | 0.25a | 12.50a | 1.50ab |
| SCLI-02 (High rate) [=DC-042] | 35.00 b | 14.75a | 0.25a | 15.00a | 0.50a |
| SCLI-03 | 27.85ab | 19.88ab | 2.28a | 22.15ab | 3.55ab |
| Avatar™ | 29.95ab | 26.25ab | 3.50a | 20.05ab | 3.58ab |
| Success™ | 32.50 b | 15.60ab | 0.50a | 17.50ab | 4.00ab |

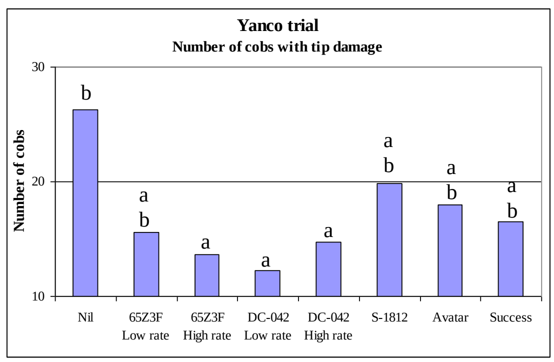
At harvest, the plots sprayed with low or high rates of SCLI-01, low or high rates of SCLI-02 or Success had significantly more undamaged cobs (Nil Dam) than the untreated plots. The plots sprayed with low or high rates of SCLI-02 or the high rate of SCLI-01 had significantly lower number of cobs with tip damage (Tip Dam) and significantly lower number of cobs with any type of grub damage (Tot Dam) than the unsprayed plots.

Side damage (Side Dam) was significantly similar in all treatments. The plots sprayed with the high rate of SCLI-02 had significantly less of grubs than the unsprayed plots (Grub #).

Graph 1 Number of cobs with no grub damage at the Yanco trial




Graph 2 Number of cobs with tip damage at the Yanco trial




Treatments sharing a common letter are not significantly different by Tukey's test at P = 0.05

<u>Whitton trial</u>

The Whitton trial was harvested on 20th February 2006. Sixty random samples were collected from each plot and assessed for grub damage. Table 35 contains the harvest results. Numbers in the same column sharing a common letter are not significantly different by Tukey's test at P = 0.05

Table 35: Harvest results for Whitton trial

| Treatment | Nil Dam | Tip Dam | Side Dam | Tot Dam | Grub # |
|---|---|---|---|---|---|
| Nil | 22.25a | 24.75 c | 13.00 c | 37.75 d | 47.00 b |
| SCLI-01 (Low rate) [=65Z3F] | 48.50 b | 10.50abc | 1.00ab | 11.50abc | 15.00a |
| SCLI-01 (High rate) [=65Z3F] | 49.75 b | 10.25ab | 0.00a | 10.25ab | 19.50a |
| SCLI-02 (Low rate) [=DC-042] | 48.50 b | 11.25abc | 0.25a | 11.50abc | 20.50ab |
| SCLI-02 (High rate) [=DC-042] | 50.75 b | 9.00a | 0.25a | 9.25a | 17.25a |
| SCLI-03 | 36.00 b | 19.00abc | 5.00 bc | 24.00 cd | 28.75ab |
| Avatar™ | 37.25 b | 20.25 bc | 2.25ab | 22.50 bcd | 33.25ab |
| Success™ | 44.00 b | 13.25abc | 2.75abc | 16.00abcd | 22.00ab |

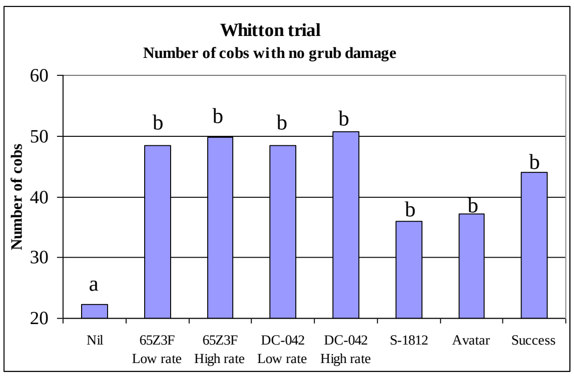
At harvest, all spray treatments had significantly more undamaged cobs (Nil Dam) than the control. The plots sprayed with the high rate of SCLI-02 or the high rate of SCLI-01 had significantly lower number of cobs with tip damage (Tip Dam) than the unsprayed plots. The plots with the high rate of SCLI-02 also had significantly lower number of cobs with tip damage than the plots sprayed with Avatar.

Except for SCLI-03 and Success, all treatments had significantly less side damage (Side Dam) than the control. The plots sprayed with the high or low rates of SCLI-02 or the high rate of SCLI-01 also had significantly lower number of cobs with side damage than the plots sprayed with SCLI-03.

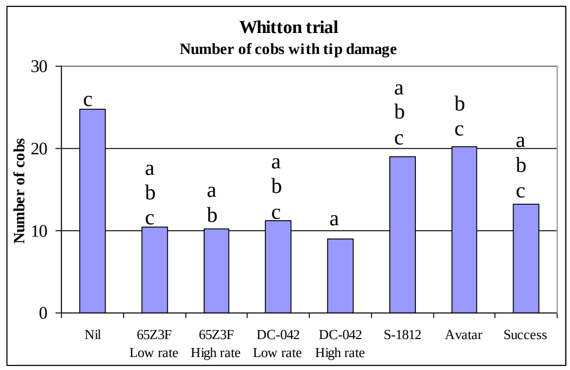
The plots sprayed with the high or low rates of SCLI-02 or the high or low rates of SCLI-01 had significantly lower number of cobs with any type of grub damage (Tot Dam) than the unsprayed plots. The high rate of SCLI-02 also had significantly lower total grub damage than SCLI-03 and Avatar while the high rate of SCLI-01 had significantly lower total grub damage than SCLI-03.

The plots sprayed with high or low rates of SCLI-01 or the high rate of SCLI-02 had significantly less grubs than on the unsprayed plots (Grub #).

Graph 3 Number of cobs with no grub damage at the Whitton trial




Graph 4 Number of cobs with tip damage at the Whitton trial




Treatments sharing a common letter are not significantly different by Tukey's test at P = 0.05

### b) 2006-07 Trials

Helicoverpa pressure was high for both trials at the beginning of spray treatments. The Yanco trial site had the highest initial pressure but the Whitton site had a higher post silking pressure with a constant egg lay after silking started. At the initial assessment for the Yanco trial there were 243 eggs and six larvae found on 280 plants (28 plots x 10 plants). At the initial assessment for the Whitton trial there were less egg numbers but a higher number of grubs found. There were 55 eggs and 29 grubs found on 240 plants (24 plots x 10 plants).

<u>Yanco trial</u>

The Yanco trial was harvested on 5th March 2007. Due to a poor plant stand, forty cobs were not able to be collected from each plot. All cobs were collected from the centre 15m of each plot and assessed for grub damage. Between 30 to 50 cobs were collected from each plot. The results are expressed in percentages due to the uneven number of cobs collected from each plot. Table 36 contains the harvest results. Numbers in the same column sharing a common letter are not significantly different by Tukey's test at P = 0.05.

Table 36: Harvest results for Yanco trial

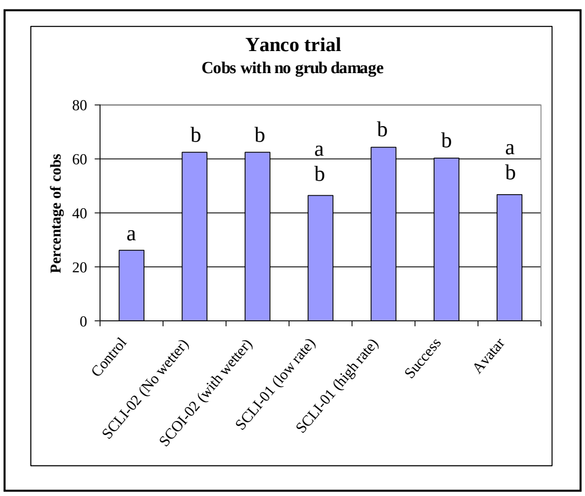
| **Treatment** | **Nil Dam (%)** | **Slight Dam (%)** | **Marketable (%)** | **Heavy Dam (%)** | **Side Dam (%)** |
|---|---|---|---|---|---|
| Control | 26.07 a | 35.06 a | 61.12 a | 30.82 b | 8.63 b |
| SCLI-02 (No wetter) [=DC-042] | 62.57 b | 20.27 a | 82.85 b | 16.35 ab | 0.81 a |
| SCLI-02 (with wetter) [=DC-042] | 62.43 b | 20.22 a | 82.65 b | 14.85 a | 0.00 a |
| SCLI-01 (low rate) [=65Z3F] | 46.32 ab | 30.41 a | 76.73 ab | 19.63 ab | 3.64 ab |
| SCLI-01 (high rate) [=65Z3F] | 64.18 b | 22.82 a | 87.00 b | 10.90 a | 2.10 a |
| Success™ | 60.38 b | 23.80 a | 84.19 b | 15.27 ab | 0.54 a |
| Avatar™ | 46.74 ab | 29.78 a | 76.52 ab | 20.62 ab | 2.86 ab |

At harvest, the plots sprayed with high rates of SCLI-01, SCLI-02 (with or without a wetter) or Success™ had significantly more undamaged cobs (Nil Dam) than the untreated plots. The plots sprayed with a low rate of SCLI-01 or Avatar™ had a significantly similar percentage of undamaged cobs to the untreated plots.

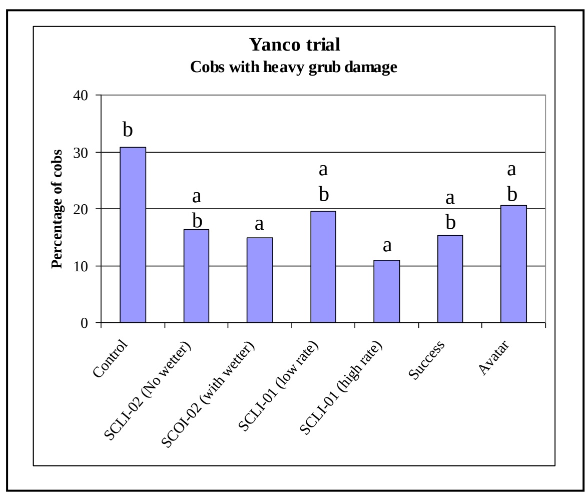
The plots sprayed with high rates of SCLI-01, SCLI-02 (with or without a wetter) or Success™ had a significantly higher percentage of marketable cobs and a significantly lower number of cobs with side damage than the unsprayed plots. The plots sprayed with a low rate of SCLI-01 or Avatar™ had a significantly similar percentage of marketable cobs and cobs with heavy grub damage to the untreated plots.

The plots sprayed with high rates of SCLI-01 and SCLI-02 with a wetter had a significantly lower percentage of cobs with heavy grub damage. The plots sprayed with a low rate of SCLI-01, SCLI-02 without a wetter, Success or Avatar had a significantly similar percentage of cobs with heavy grub damage. Slight damage was statistically similar in all treatments.

Graph 5 Number of cobs with no grub damage at the Yanco trial




Graph 6 Number of cobs with tip damage at the Yanco trial




Treatments sharing a common letter are not significantly different by Tukey's test at P = 0.05.

<u>Whitton trial</u>

The Whitton trial was harvested on 6th March 2007. Forty random samples were collected from each plot and assessed for grub damage. To be consistent with the Yanco trial the results are expressed in percentages. Table 37 contains the harvest results. Numbers in the same column sharing a common letter are not significantly different by Tukey's test at P = 0.05.

Table 37: Harvest results for Whitton trial

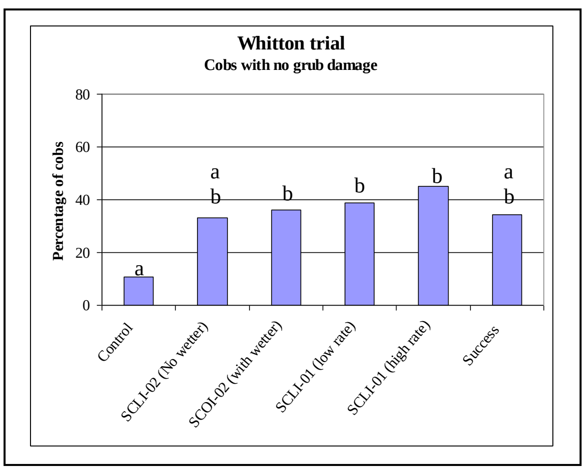
| Treatment | Nil Damage (%) | Slight Damage (%) | Marketable (%) | Heavy Damage (%) | Side Damage (%) |
|---|---|---|---|---|---|
| Control | 10.63 a | 49.38 a | 60.00 a | 35.63 b | 4.38 a |
| SCLI-02 (No wetter) [=DC-042] | 33.13 ab | 51.88 a | 85.00 b | 14.38 a | 0.63 a |
| SCLI-02 (with wetter) [=DC-042] | 36.25 b | 45.63 a | 81.88 b | 15.63 a | 2.50 a |
| SCLI-01 (low rate) [=65Z3F] | 38.75 b | 41.25 a | 80.00 ab | 18.75 a | 1.25 a |
| SCLI-01 (high rate) [=65Z3F] | 45.00 b | 45.63 a | 90.63 b | 10.00 a | 0.63 a |
| Success™ | 34.38 ab | 50.00 a | 84.38 b | 14.38 a | 1.25 a |

At harvest, the plots sprayed with low or high rates of SCLI-01 and SCLI-02 with wetter had a significantly higher percentage of undamaged cobs (Nil Damage) than the untreated plots. The plots sprayed with SCLI-02 without a wetter or Success™ had a significantly similar percentage of undamaged cobs to the untreated plots.

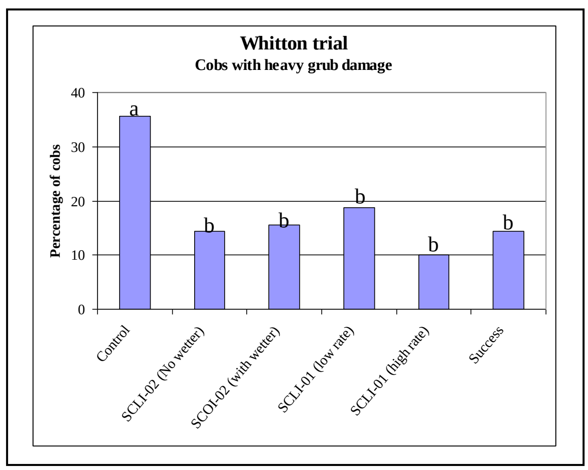
The plots sprayed with high rates of SCLI-01, SCLI-02 (with or without a wetter) or Success™ had a significantly higher percentage of marketable cobs than the unsprayed plots. The plots sprayed with a low rate of SCLI-01 had a significantly similar percentage of marketable cobs to the untreated plots.

All treatments had a significantly lower number of cobs with heavy damage than the unsprayed plots. Slight damage and side damage was significantly similar in all treatments.

Graph 7 Number of cobs with no grub damage at the Whitton trial




Graph 8 Number of cobs with tip damage at the Whitton trial

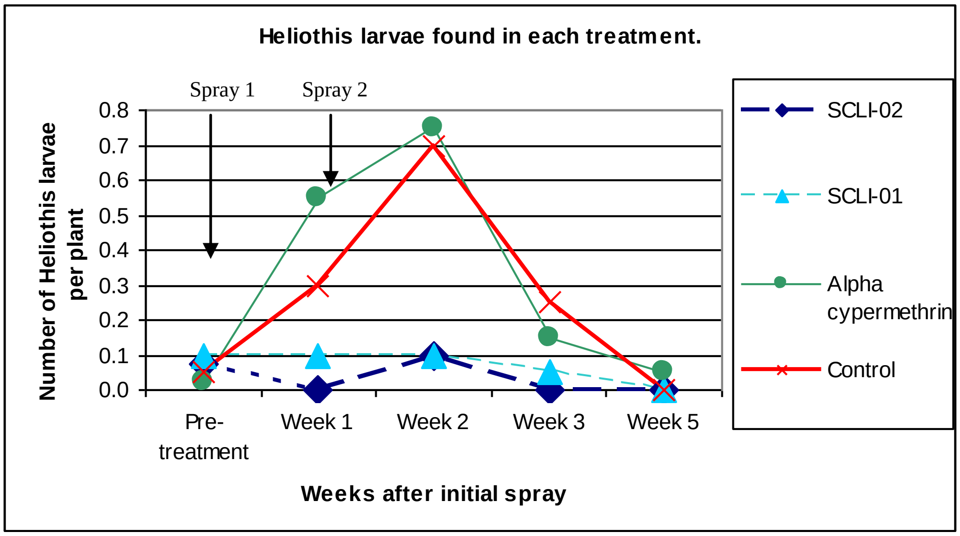



Treatments sharing a common letter are not significantly different by Tukey's test at P = 0.05.

### c) Additional 2007 non-replicated Trial

## Helicoverpa control:

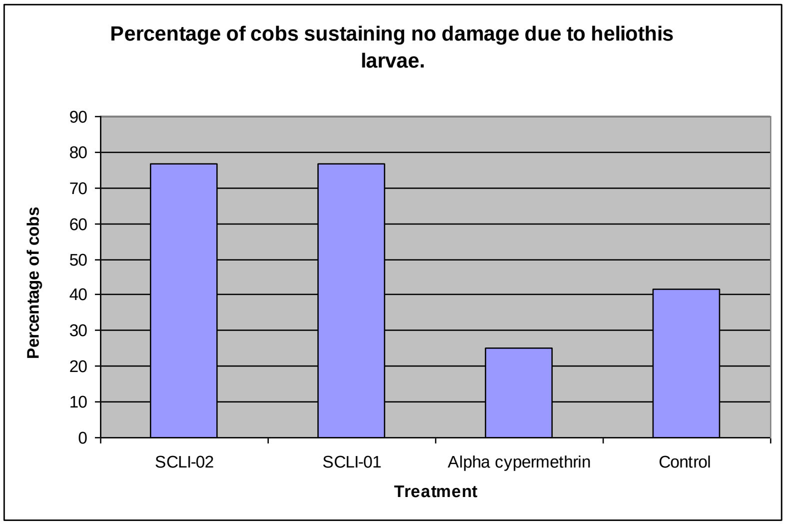
Graph 9: Helicoverpa larvae numbers per plant for each treatment from pre-treatment through to post harvest.



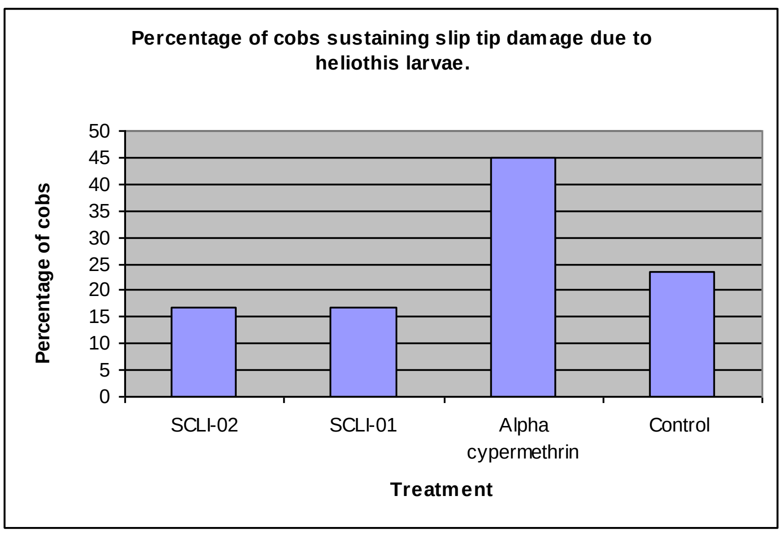

The number of helicoverpa larvae observed at pre-treatment (tasselling) was very low at 1 or less on every ten plants for all of the treatment plots. The number of larvae in the SCLI-02 and SCLI-01 treated plots did not exceed 1 on every ten plants during the entire trial period. Larvae numbers found in the alpha cypermethrin and control treatments greatly increased during silking with a maximum of three larvae to every four plants found in the alpha cypermethrin plot in Wk 2 making a total of fifteen per twenty plants. Larvae numbers in the control plot reached fourteen per twenty plants just one less than what was observed in the alpha cypermethrin plot. Helicoverpa larvae numbers dropped back down to less than 1 per 20 plants for each of the treatments at post harvest, this population drop is most likely due to reduced appeal of the crop to adult moths as the crop began to senesce.

<u>Cob assessments for damage from helicoverpa larvae.</u>
The following are graphs showing results of the cob assessments conducted as part of the harvest assessment on 1st March 2007; week four. Sixty cobs from each treatment were assessed according to the level or location of damage incurred by feeding of helicoverpa larvae.

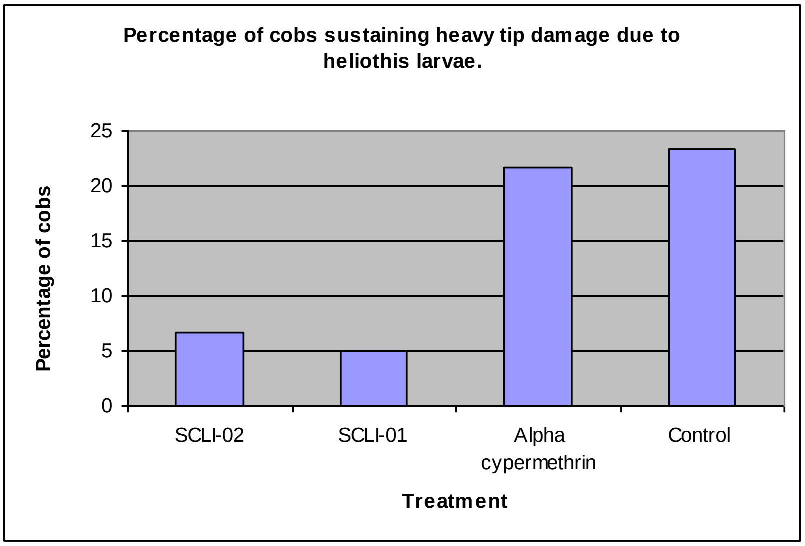
Graph 10: Percentage of cobs within each treatment that did not have any damage from helicoverpa larvae.



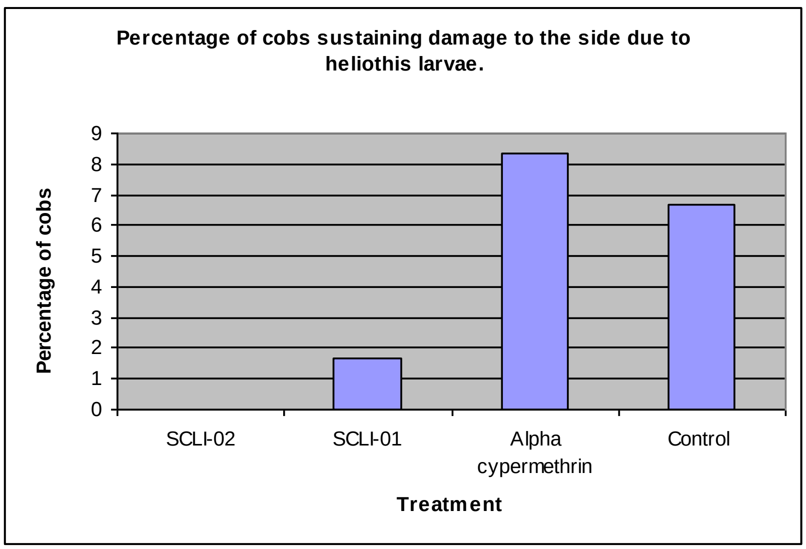

Graph 11: Percentage of cobs from each treatment that sustained a slight level of damage to the tip of the cob.




Graph 12: Percentage of cobs with heavy (significant) tip damage.



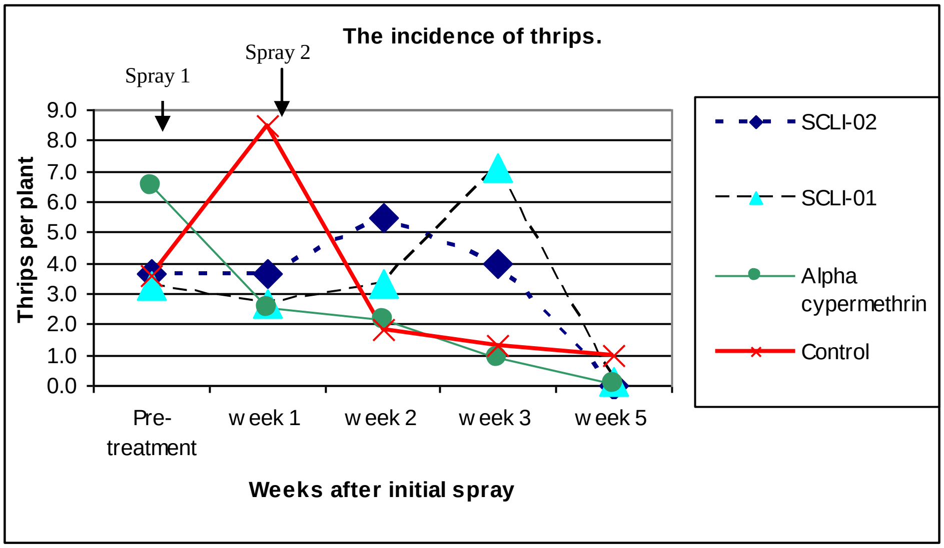

Graph 13: Percentage of cobs with side (significant) damage due to helicoverpa larvae.




Results were very similar for the plots treated with SCLI-02 and SCLI-01 with 77% sustaining no damage from helicoverpa larvae. For both the SCLI-02 and SCLI-01 treatments only 17% of the cobs sustained slight tip damage leaving only 7% of the cobs with significant damage. For the alpha cypermethrin and control plots, 27% and 42% respectively of cobs remained free of damage and 45% and 23% respectively sustained slight tip damage. Thirty percent of the cobs from both the alpha cypermethrin and control plots sustained significant damage from helicoverpa larvae.

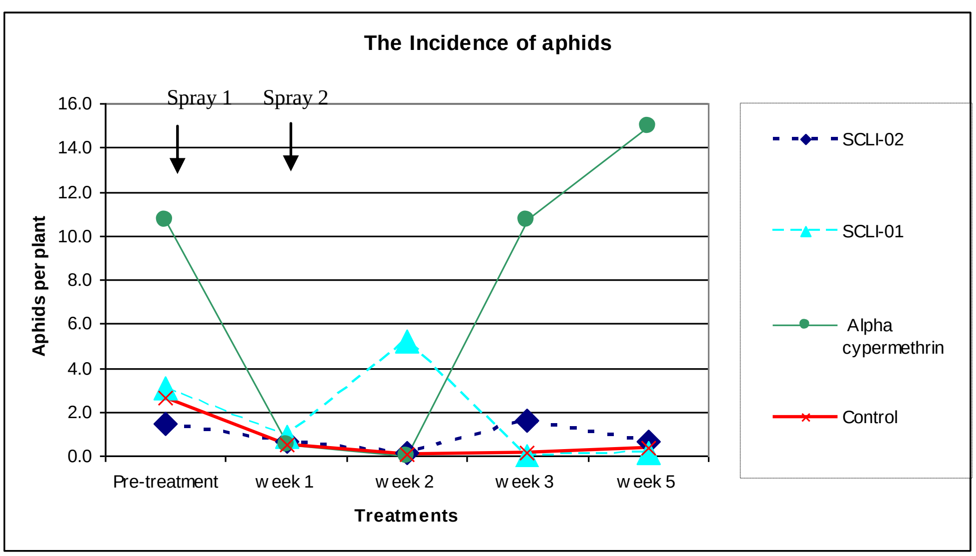
## Secondary Pests:

Graph 14: The number of thrips per plant from pre-treatments through to post harvest.

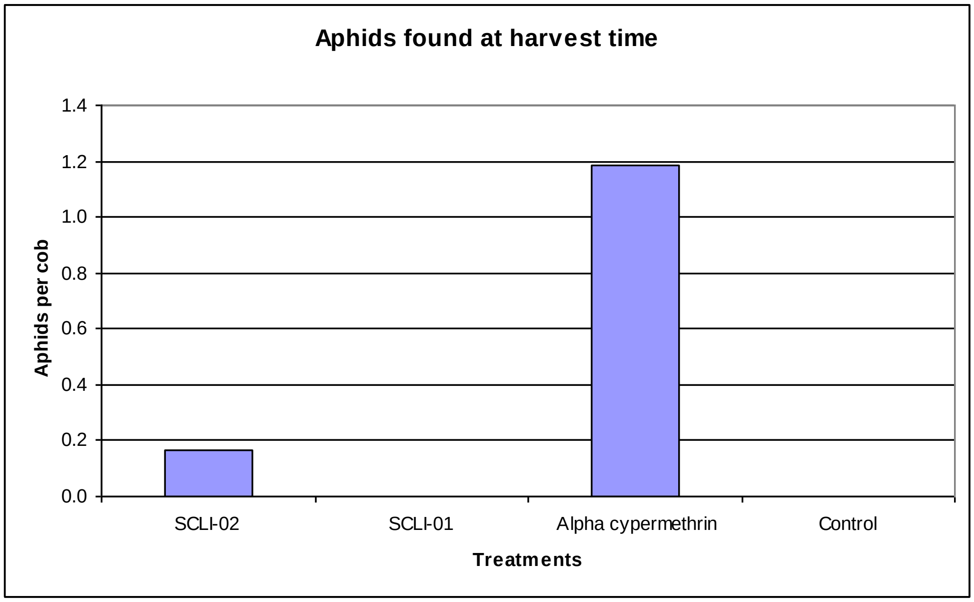



The results above indicate in Wk1 that all of the sprayed treatments have moderate efficacy against thrips as compared to the population present in the control. However in Wk2 and Wk3 thrips numbers in the SCLI-01 and SCLI-02 treated plots exceeded those found in the control plot indicating that they have no efficacy upon thrips. The thrips numbers in the alpha cypermethrin treated plot did not exceed 3 per plant following the initial spray. The thrips populations dropped to one in ten plants or less for each of the treatments excluding the control in week five. It is difficult to make observations from these results due to the variability evident between the plots in the pre-treatment period and the fluctuating numbers of thrips throughout the trial. As a whole the results of chemical effects upon thrips are inconclusive and it is difficult to draw any conclusions from this data.

Graph 15: The number of aphids per plant from pre-treatments through to post harvest.



Graph 16: The incidence of aphids for each of the treatments at the harvest assessment; 1st March 2007.




Results from the crop monitoring indicate that SCLI-02 had little or no affect as compared to the control treatment, upon the aphid population. Results for SCLI-01 are more difficult to interpret with the aphid population reaching 5 per plant in Wk2 as compared to only one to every ten plants and zero in the SCLI-02 and the control plots respectively. Numbers then dropped down to zero Wk3. The low aphid numbers in the control and new chemistry plots from Wk3 on could be caused by the beneficial insect populations i.e. ladybird beetles that can keep aphid populations in check. It is known that alpha cypermethrin is toxic to aphids. The results supported this fact by revealing very low numbers for the first 2 weeks following the first spray application. At Wk3 the alpha cypermethrin plot showed an increase in the aphid population to over 10 aphids per plant. It is likely that alpha cypermethrin was toxic to aphid predators and parasitoids thereby causing a pest resurgence once residue levels had been reduced. Aphid predators can be effective at keeping the aphid population in check as was observed in the other three treatment blocks. The overhead irrigation may have washed off the alpha cypermethrin residue allowing recolonisation within two weeks of the last application. Relatively large numbers of aphids were found in cobs from the alpha cypermethrin treated plot as compared to the other treatments supporting the observations made from the field monitoring.

## Conclusion:

With no replication, the purpose of this trial was to observe population trends within the different treatment plots. With predominantly low insect numbers throughout the trial and typically highly variable pre-treatment counts interpretations from the results were restricted.

The two new chemicals SCLI-02 and SCLI-01 both demonstrated very good control of helicoverpa as compared to the control and alpha cypermethrin. The results show that by Wk5 (post harvest), the population numbers in each of the treatments for most of the pests and beneficials (excluding aphids) had come together. This is most likely due to insect migration within and around the trial block. Any insecticide residues were likely to have been washed off the crop from the overhead irrigation by that stage. Therefore all plots were likely to be potential habitats for insect species from neighbouring plots.

The toxicity of alpha cypermethrin upon the secondary pests and beneficial insects was usually very high. Exceptions to this were observed with the thrips, lacewing and pirate bug populations where survival rates were either quite high (as for thrips) or just inconsistent in the monitoring results from Wk1 and Wk2. Field scouting dates for Wk 1 and Wk2 were sprayed five and six days respectively before the plots were monitored. Therefore results from week one and two are likely to indicate more accurately what impact the different treatments had upon the insect populations than those from Wks 3 and 5.

### d) 2007-08 Trials

Two trials were conducted during the 2007/08 season at the Yanco Agricultural Institute, NSW, to assess the efficacy of different spray programmes that were based either on new generation, narrow spectrum chemicals or older broad spectrum chemicals for controlling helicoverpa (*Helicoverpa armigera*). Two spray programs (treatments) evaluated the use of SCLI-02 when first applied at silking.

Tables 38 to 41 contain the harvest assessments. Numbers in the same column sharing a common letter are not significantly different by LSD test at P = 0.05.

Table 38: Harvest assessment on 40 cobs for Trial 1

| Treatment | | No Damage | Very little Damage | Small Damage | Heavy Damage | Very heavy damage |
|---|---|---|---|---|---|---|
| T1 | Starting at Tasselling | 13.75 b | 8.00 c | 13 00 a | 5.00 a | 0.25 a |
| T2 | Starting at silking | 14.50 b | 9.00 bc | 11.25 a | 5.25 a | 0.00 a |
| T3 | Grower with High Water | 12.00 b | 6.75 bc | 11.25 a | 9.50 b | 0.50 a |
| T4 | Grower with Low Water | 5.00 a | 6.50 b | 14.00 a | 12.75 c | 1.75 b |
| T5 | Control | 2.50 a | 2.25 a | 13 00 a | 17.50 d | 4.75 c |

Table 39: Harvest assessment on 40 cobs grouped into marketable categories for Trial 1

| Treatment | | Marketable for fresh market | Marketable for Processing | Unmarketable | Number of Grubs |
|---|---|---|---|---|---|
| T1 | Starting at Tasselling | 21.75 cd | 34.75 d | 5.25 a | 3.25 a |
| T2 | Starting at silking | 23.50 d | 34.75 d | 5.25 a | 2.00 a |
| T3 | Grower with High Water | 18.75 c | 30.00 c | 10.00 b | 12.00 b |
| T4 | Grower with Low Water | 11.50 b | 25.50 b | 14.50 c | 11.50 b |
| T5 | Control | 4.75 a | 17.75 a | 22.25 d | 26.50 c |

Table 40: Harvest assessment on 40 cobs for Trial 2

| Treatment | | No Damage | Very little Damage | Small Damage | Heavy Damage | Very heavy damage |
|---|---|---|---|---|---|---|
| T1 | Starting at Tasselling | 14.00 c | 6.25 a | 12.50 a | 7.25 a | 0.00 a |
| T2 | Starting at silking | 14.75 c | 6.75 a | 12.50 a | 5.75 a | 0.25 a |
| T3 | Grower with High Water | 8.00 b | 6.50 a | 9.75 a | 13.75 b | 2.00 b |
| T4 | Grower with Low Water | 6.75 ab | 4.25 a | 9.00 a | 16.25 b | 3.75 c |
| T5 | Control | 2.75 a | 2.50 a | 7.50 a | 20.25 c | 7.00 d |

Table 41: Harvest assessment on 40 cobs grouped into marketable categories for Trial 2

| Treatment | | Marketable for fresh market | Marketable for Processing | Unmarketable | Number of Grubs |
|---|---|---|---|---|---|
| T1 | Starting at Tasselling | 20.25 c | 32.75 d | 7.25 a | 2.50 a |
| T2 | Starting at silking | 21.50 c | 34.00 d | 6.00 a | 2.50 a |
| T3 | Grower with High Water | 14.50 b | 24.25 c | 15.75 b | 12.75 b |
| T4 | Grower with Low Water | 11.00 b | 20.00 b | 20.00 c | 15.00 b |
| T5 | Control | 5.25 a | 12.75 a | 27.25 d | 15.75 b |

Cobs suitable for the fresh market - Treatments T1 and T2 had the highest number of cobs suitable for the fresh market in both trials. Treatment T2 was significantly similar to T1 and significantly higher than the other 3 treatments in both trials. Treatment T1 was significantly similar to T2 and T3 in Trial 1, but significantly higher than Treatments T3, T4 and T5 in Trial 2.

Treatment T3 had a significantly higher number of cobs suitable for the fresh market than T4 and T5 in Trial 1. Treatment T3 was statistically similar to T4 in Trial 2, but significantly higher than T5. Treatment T5 had a significantly lower number of cobs suitable for the fresh market than all treatments in both trials.

Cobs suitable for the processing market - Treatments T1 and T2 had the highest number of cobs suitable for the processing market in both trials. Treatments T1 and T2 were similar in both trials and significantly higher than the other 3 treatments.

Treatments T3 had a significantly higher number of cobs suitable for the processing market than T4 and T5 in both trials. Treatment T5 had a significantly lower number of cobs suitable for the processing market than all other treatments in both trials.

Cobs not suitable for any market - Treatment T5 had statistically the highest number of unmarketable cobs in both trials. T4 had a statistically higher number of unmarketable cobs than T3, T2 and T1 in both trials. T3 had a statistically higher number of unmarketable cobs than T2 and T1 in both trials. Treatments T1 and T2 had a statistically lower number of unmarketable cobs than all other treatments, but were statistically similar to each other.

Number of larvae found on cobs - Treatment T5 had statistically the highest number of grubs found in Trial l, where treatments T1 and T2 had statistically the lowest number of grubs. Also in Trial 1 treatments T3 and T4 had statistically more grubs than T1 and T2, but less than T5. Treatments T5, T4 and T3 had statistically the highest number of grubs found in Trial 2, where treatments T1 and T2 had statistically the lowest number of grubs.

Tables 42 and 43 list the final beneficial insect count. Numbers in the same column sharing a common letter are not significantly different by LSD test at P = 0.05.

Table 42: Beneficial insect count per 20 plants found in Trial 1 on 29/1/08

| Treatment | | Ladybird beetles | Other beetles | Lacewings | Predatory bugs | Spiders |
|---|---|---|---|---|---|---|
| T1 | Starting at Tasselling | 0.00 a | 9.25 b | 1.75 a | 1.75 a | 0.50 a |
| T2 | Starting at silking | 0.00 a | 11.25 b | 0.25 a | 1.25 a | 0.50 a |
| T3 | Grower with High Water | 0.50 a | 1.50 a | 0.00 a | 0.00 a | 0.25 a |
| T4 | Grower with Low Water | 0.00 a | 4.25 a | 0.00 a | 1.25 a | 0.00 a |
| T5 | Control | 1.50 a | 17.75 c | 1.25 a | 4.25 a | 0.25 a |

Table 43: Beneficial arthropod count per 20 plants found in Trial 2 on 29/1/08

| Treatment | | Ladybird beetles | Other beetles | Lacewings | Predatory bugs | Spiders |
|---|---|---|---|---|---|---|
| T1 | Starting at Tasselling | 0.25 a | 11.75 b | 0.75 a | 1.50 a | 0.00 a |
| T2 | Starting at silking | 0.00 a | 12.50 b | 0.25 a | 0.50 a | 0.50 a |
| T3 | Grower with High Water | 0.00 a | 2.75 a | 0.00 a | 0.25 a | 0.75 a |
| T4 | Grower with Low Water | 0.00 a | 4.25 a | 0.00 a | 1.75 a | 0.25 a |
| T5 | Control | 0.50 a | 29.00 c | 0.50 a | 2.00 a | 0.25 a |

Treatment T5 (control) had significantly higher numbers of “other beetles” than all the 4 spray treatments. Treatments T1 and T2 (using narrow spectrum chemicals) had significantly higher numbers of “other beetles” than treatments T3 and T4 (using broad spectrum chemicals). The insects recorded as “other beetles” included flower, pollen and rove beetles. No distinction was made between these three beetles at the time of scouting (numbers were recorded collectively and it was impossible to separate them later). It was generally observed that flower beetles were the most abundant beetle in the trials, with pollen beetles seen in low numbers and rove beetles rarely observed. Even though the flower beetle was observed and recorded with “other beetles”, it is not considered a beneficial insect in sweet corn.

There was no statistical difference in numbers of ladybird beetles, lacewings, predatory bugs or spiders between any of the treatments. A non-significant trend was observed for lacewings and predatory bugs with higher numbers observed in treatments T1, T2 and T5 than those observed in the treatments T3 and T4 that relied on broad spectrum sprays.

## 5.12 North Queensland – Soft Options - Results

### Helicoverpa management

#### a) & b) Field Trials 1& 2 – Results

Trials 1 and 2 (2006) results and cob damage assessment are shown in Table 45 and 46. In both trials, the SCLI-02 and SCLI-01 plots had the highest number of cobs free of damage (85 to 97%), compared to the untreated control.
There were no significant differences between the levels of control achieved by the three rates of SCLI-02. All three rates (0.5 x label, 1 x label and 2 x label) were effective against helicoverpa and only 3.3 - 15% of cobs in the SCLI-02 treated plots were damaged, while 45 to 55% of cobs in the untreated control plots were damaged (Table 45 & 46). Avatar™ had a significantly higher number of marketable cobs (82%) than the untreated control. Cob damage was highest in SCLI-03 treated plots (55%).

**Table 45. Levels of cob damage under different insecticide treatments inTrial 1 in 2006**

| Treatments | Application rate / ha | Nil damage % (for fresh market) | Tip damage % (for pre-pack) * | Deep damage % (unmarketable) |
|---|---|---|---|---|
| SCLI-01 | 100 ml | 95.0 b | 5.0 b | 0.0 |
| SCLI-02 | 100 ml | 88.5 b | 10.0 b | 1.5 |
| SCLI-02 | 200 ml | 85.0 b | 11.7 b | 3.3 |
| SCLI-03 | 200 ml | 55.0 a | 36.7 a | 8.3 |
| Avatar™ | 250 g | 83.3 b | 11.7 b | 5.0 |
| SCSI-01 | 200 ml | 56.7 a | 36.7 a | 6.6 |
| Untreated | N/A | 45.0 a | 36.7 a | 18.3 |

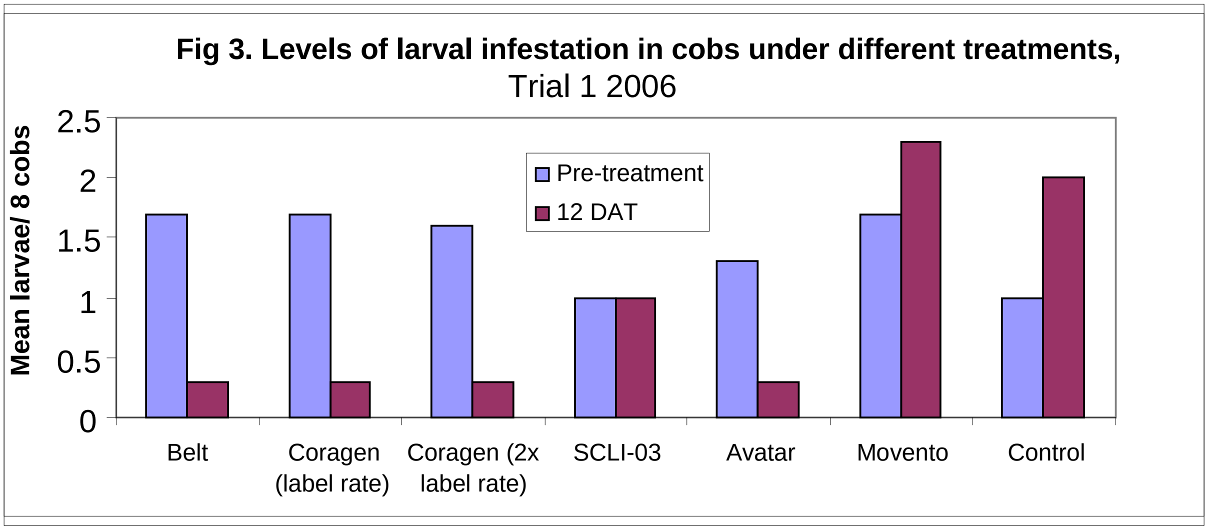
Means in a column followed by same letters are not significantly different (P > 0.05, LSD).
(* = Tip damage and deep damage were combined for statistical analysis)

**Table 46. Levels of cob damage under different insecticide treatments in Trial 2 in 2006**

| Treatments | Application rate / ha | Nil damage % (for fresh market) | Tip damage % (for pre-pack) | Deep damage % (unmarketable) |
|---|---|---|---|---|
| SCLI-01 | 100 ml | 91.7 b | 6.7 b | 1.6 |
| SCLI-02 | 50 ml | 95.0 b | 5.0 b | 0.0 |
| SCLI-02 | 100 ml | 96.7 b | 3.3 b | 0.0 |
| Avatar™ | 250 g | 81.7 b | 11.7 b | 6.3 |
| SCSI-01 | 200 ml | 71.6 a | 23.3 a | 5.0 |
| Mite-01 | 350 ml | 68.3 a | 26.7 a | 5.0 |
| SCSI-03 | 25 ml per 100m row | 63.3 a | 30.0 a | 6.7 |
| Untreated | N/A | 65.4 a | 30.6 a | 4.0 |

Means in a column followed by same letters are not significantly different (P > 0.05, LSD).
(* = Tip damage and deep damage were combined for statistical analysis)

Helicoverpa larval infestations mostly comprised small and medium sizes with pre-treatment larval densities ranging from 1.0 to 1.7 per 8 cob. Avatar™, SCLI-02 and SCLI-01 performed well, and effectively controlled helicoverpa infestations in the cobs. At 12 days after treatment (DAT), larval infestation of cobs was also lowest in the SCLI-01, SCLI-02 and Avatar™ plots (reduction of 77-83%) and highest in the untreated, SCSI-01 and SCLI-03 plots (Fig. 3).




### c) Field Trial 3 – Results

SCLI-02 and SCLI-01 were included in Trial 3 in 2007 to determine their effectiveness against helicoverpa. Both products performed well and effectively reduced cob damage. SCLI-02 and SCLI-01 plots had the highest number of cobs free of damage (93 to 97%) compared to the untreated control (68%) (Table 47).

**Table 47. Levels of cob damage under different insecticide treatments, Trial 3 in 2007**

| Treatments | Application rate / ha | Nil damage % (for fresh market) | Tip damage % (for pre-pack) | Heavy damage % (unmarketable) |
|---|---|---|---|---|
| SCLI-01 | 100 ml | 97.3 b | 0.0 | 2.7 |
| SCLI-02 | 50 ml | 93.5 b | 2.6 | 3.9 |
| SCSI-01 | 200 ml | 66.7 a | 26.7 | 6.7 |
| Chess™ | 200 g | 69.3 a | 25.3 | 5.4 |
| Primor™ | 650 g | 68.0 a | 28.0 | 4.0 |
| Untreated | N/A | 68.0 a | 18.7 | 13.3 |

Means in a column followed by same letters are not significantly different (P > 0.05, LSD).

### d) Field Trial 4 – Results

In Trial 4, SCLI-02 and SCLI-01 were combined with Success™ (industry standard) to evaluate efficacy against helicoverpa. Pre-treatment egg and larval densities ranged from 1.1 to 3.2 per 10 cobs (Fig 2). All three insecticides performed well, and had 83 to 86% of cobs free of damage. No significant differences were found between the three treatments (Table 48).

Fig 4. Heliothis eggs and larval density in pre-treatment counts, Trial 4 2007

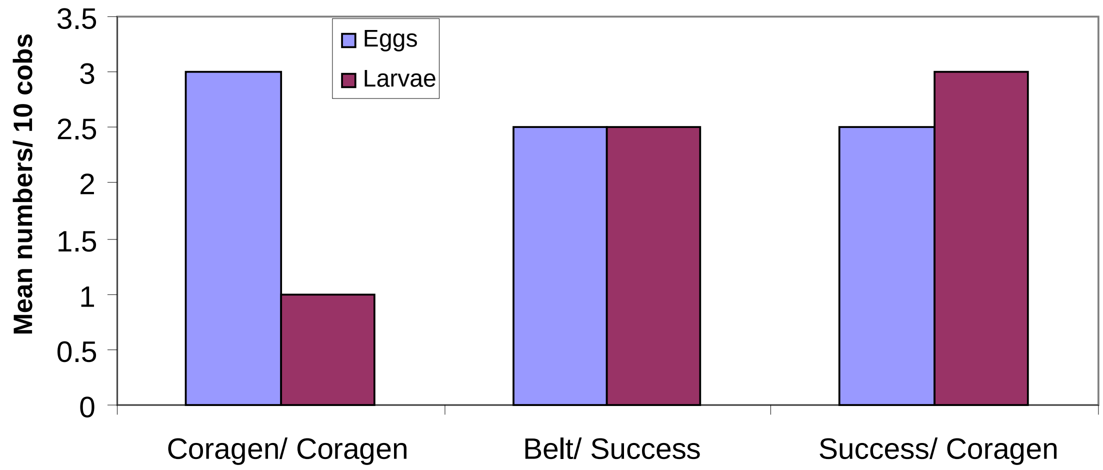



**Table 48. Levels of cob damage under different insecticide rotations in Trial 4 in 2007**

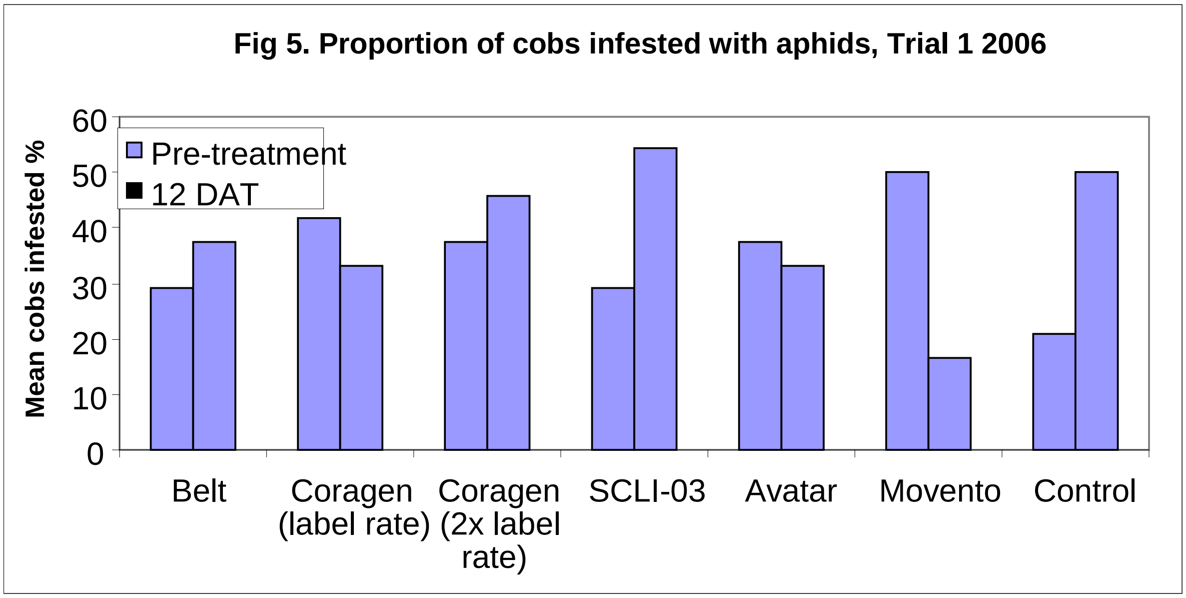
| Insecticide rotations | First harvest | | | Second harvest | | |
|---|---|---|---|---|---|---|
| | Nil cob damage | Tip damage | Deep damage | Nil cob damage | Tip damage | Deep damage |
| SCLI-02/ SCLI-02 | 83 a | 10.2 | 6.8 | 77.7 a | 3.7 | 18.6 |
| SCLI-01/ Success™ | 86.3 a | 6.9 | 6.8 | 73.8 a | 12.2 | 14.0 |
| Success™/ SCLI-02 | 83.3 a | 5.0 | 11.7 | 79.7 a | 6.8 | 13.5 |

Means in a column followed by same letters are not significantly different (P > 0.05, LSD

**Aphid control**

**a) Field Trial 1 – Results**

In Trial 1, aphid numbers increased to the highest level at the flowering and silking periods (July/ Aug). In the pre-treatment counts, aphid densities ranged from 18 to 100 per cob, when 21 to 42% of the cobs had moderate to heavy infestations (Fig 5).




SCSI-01 performed well and effectively controlled aphid infestations in this trial. At the post-treatment count (12 DAT), the aphid infestations in the SCSI-01 treated cobs were significantly lower than in the untreated control (Fig 5). At the harvest (39 DAT), the SCSI-01 plots had a highest proportion of cobs free of infestation (56.7%), compared to the untreated control (3.3%) (Table 49). SCSI-01 had a significantly higher number of marketable cobs (82%) than all other treatments (Table 50). The helicoverpa insecticides (SCLI-01, SCLI-02, and Avatar™) were ineffective against aphids.

**Table 49. Aphid infestation under different insecticide treatments, Trial 1, 2006**

| Treatments | Application rate / ha | Mean number of cobs infested with aphids (%) | | |
|---|---|---|---|---|
| | | Nil infestation | Slight infestation | Heavy infestation |
| SCLI-01 | 100 ml | 5.0 a | 45.0 a | 50.0 a |
| SCLI-02 | 100 ml | 10.0 a | 40.0 a | 60.0 a |
| SCLI-02 | 200 ml | 0.0 a | 23.3 a | 76.7 a |
| SCSI-03 | 200 ml | 0.0 a | 26.7 a | 73.3 a |
| Avatar™ | 250 g | 10.0 a | 56.7 a | 33.3 a |
| SCSI-01 | 200 ml | **56.7 b** | 38.3 a | **3.0 b** |
| Untreated | N/A | 3.3 a | 43.3 a | 53.3 a |

Means in a column followed by same letters are not significantly different (P > 0.05, LSD).

**Table 50. Percentage of marketable cobs based on aphid infestation levels in Trial 1 2006**

| Treatments | Application rate / ha | % Mean marketable cobs | | |
|---|---|---|---|---|
| | | Suitable for fresh market | Suitable for pre-pack | Unmarketable |
| SCLI-01 | 100 ml | 10.0 a | 40.0 a | 50.0 a |
| SCLI-02 | 100 ml | 18.3 a | 21.7 a | 60.0 a |
| SCLI-02 | 200 ml | 8.3 c | 15.0 a | 76.7 a |
| SCSI-03 | 200 ml | 0.0 c | 26.7 a | 73.3 a |
| Avatar™ | 250 g | 21.7 a | 45.0 a | 33.3 a |
| SCSI-01 | 200 ml | **86.7 b** | **8.3 b** | **3.3 b** |
| Untreated | N/A | 21.6 a | 25.0 a | 53.3 a |

Means in a column followed by same letters are not significantly different (P > 0.05, LSD).

**b) Field Trial 2 – Results**

In Trial 2, the aphid numbers were very low (0 to 8%) during the flowering and silking periods (Sep / Oct), and as a consequence, aphid products were not evaluated in this trial.

**c) Field Trial 3 – Results**

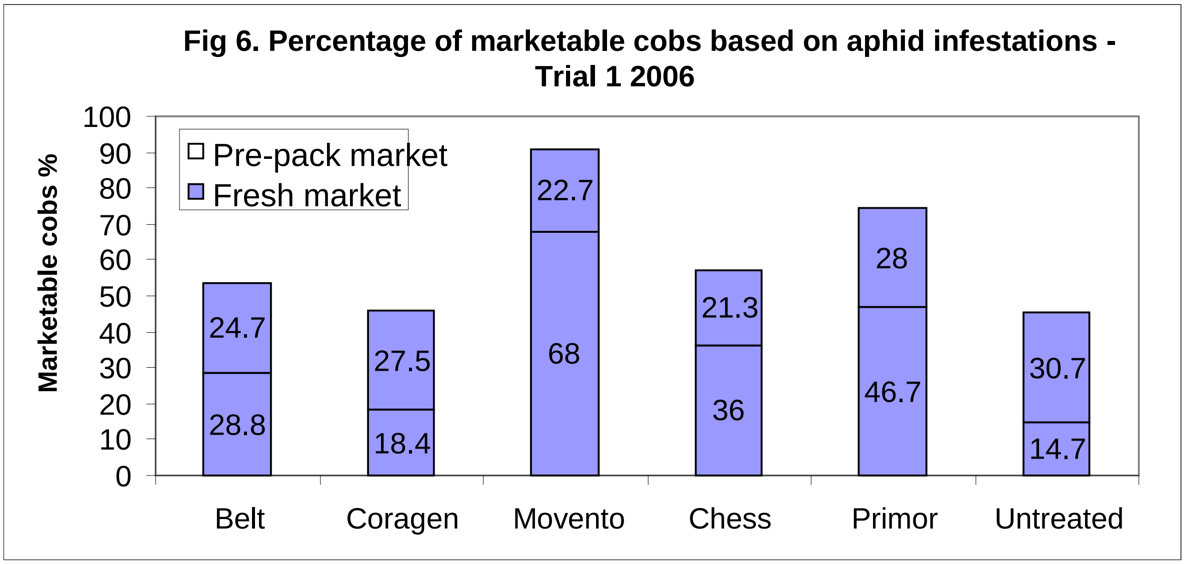
In Trial 3 (2007), the aphid infestation was very high at silking (July/ Aug). Three insecticides (SCSI-01, Chess™ and Primor™) were evaluated against aphids. At harvest (28 DAT), SCSI-01 had a significantly lower aphid infestation than the untreated control (Table 51).

**Table 51. Levels of aphid infestation under different insecticide treatments in Trial 3 in 2007**

| Treatments | Application rate / ha | Mean cobs infested with aphids (%) | | |
|---|---|---|---|---|
| | | Low infestation | Moderate infestation | Heavy infestation |
| SCLI-01 | 100 ml | 28.8 a | 24.7 a | 47.9 a |
| SCLI-02 | 50 ml | 18.4 a | 27.5 a | 54.1 a |
| SCSI-01 | 200 ml | **66.7 b** | 22.7 a | **10.7 b** |
| Chess™ | 200 g | 36.0 b | 21.3 a | 42.7 a |
| Pirimor™ | 650 g | 46.7 b | 28.0 a | 25.3 b |
| Untreated | N/A | 14.7 a | 30.7 a | 54.7 a |

Means in a column followed by same letters are not significantly different (P > 0.05, LSD).

Although the Pirimor™ and Chess™ treatments significantly reduced aphid numbers compared with control, and they all resulted in higher cob contamination than in the SCSI-01 treatment. Chess™ did not perform well in controlling corn aphids during the high pest pressure period. Pirimor™ was moderately effective. SCSI-01 had a significantly higher proportion of marketable cobs (68%) than all the other treatments (Fig 6).




**Mites Control**

**a) Field Trial 2 – Results**

In Trial 2, mite numbers peaked in the crop one week before silking, therefore treatments were applied at the early silking stage.

Mite-01 and SCSI-01 performed well against mites. At the post-treatment count (24 DAT), leaves collected from the Mite-01 plots had significantly lower numbers of mites than that in untreated control (Fig 7).

At the harvest (35 DAT), SCSI-01 and Mite-01 plots had the highest proportion of cobs free of mite infestations (35 and 28%) compared with the untreated control (0.0%) (Table 52), and they had significantly lower percentage of unmarketable cobs (28.3 and 16.7%) than all other treatments (Fig 8). Other insecticides (SCLI-01, SCLI-02, and Avatar™) were ineffective in controlling mites in the cobs.

**Table 52. Percentage of cobs infested with mites under different insecticide treatments, Trial 2 in 2006**

| Treatments | Application Rate / ha | Mean number of cobs infested with mites (%) | | |
|---|---|---|---|---|
| | | Nil infestation | Slight infestation | Heavy infestation |
| SCLI-01 | 100 ml | 13.3 a | 40.0 a | 46.7 a |
| SCLI-02 | 50 ml | 5.0 a | 35.0 a | 60.0 a |
| SCLI-02 | 100 ml | 10.0 a | 26.6 a | 63.3 a |
| Avatar™ | 250 g | 0.0 a | 28.4 a | 71.7 a |
| SCSI-01 | 200 ml | 35.0 b | 36.7 a | 28.3 b |
| Mite-01 | 350 ml | 28.3 b | 55.0 b | 16.7 b |
| TI 435 | 25 ml per 100m row | 3.3 a | 25.0 a | 44.4 a |
| Untreated | N/A | 0.0 a | 36.9 a | 63.1 a |

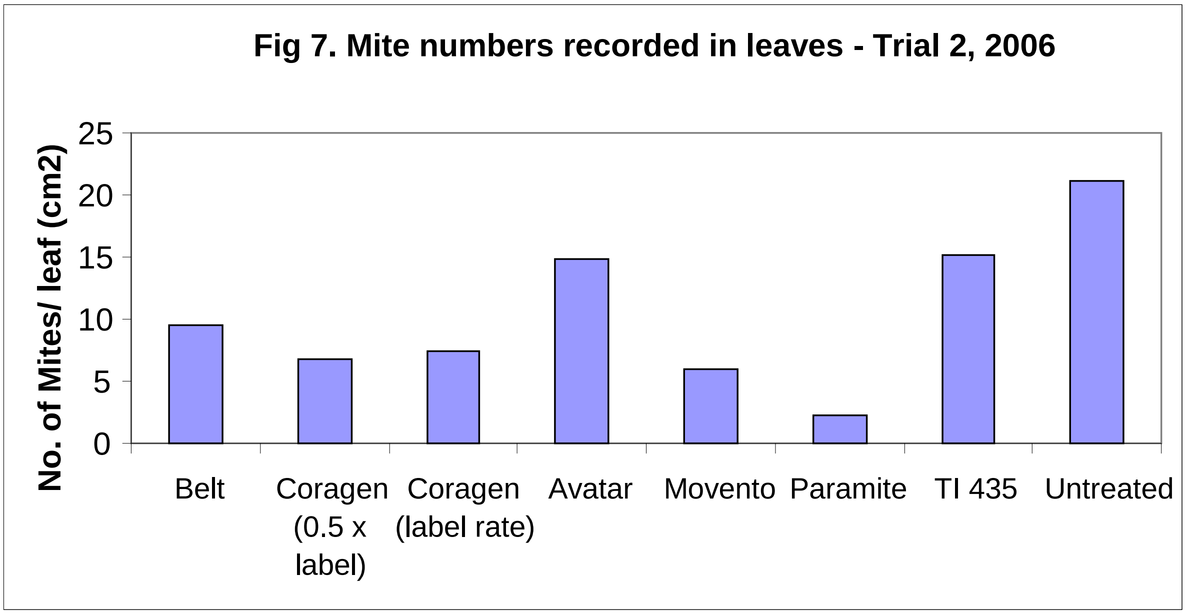


Fig 7. Mite numbers recorded in leaves - Trial 2, 2006
No. of Mites/ leaf (cm2)
25
20
15
10
5
0
Belt
Coragen (0.5 x label)
Coragen (label rate)
Avatar
Movento
Paramite
TI 435
Untreated

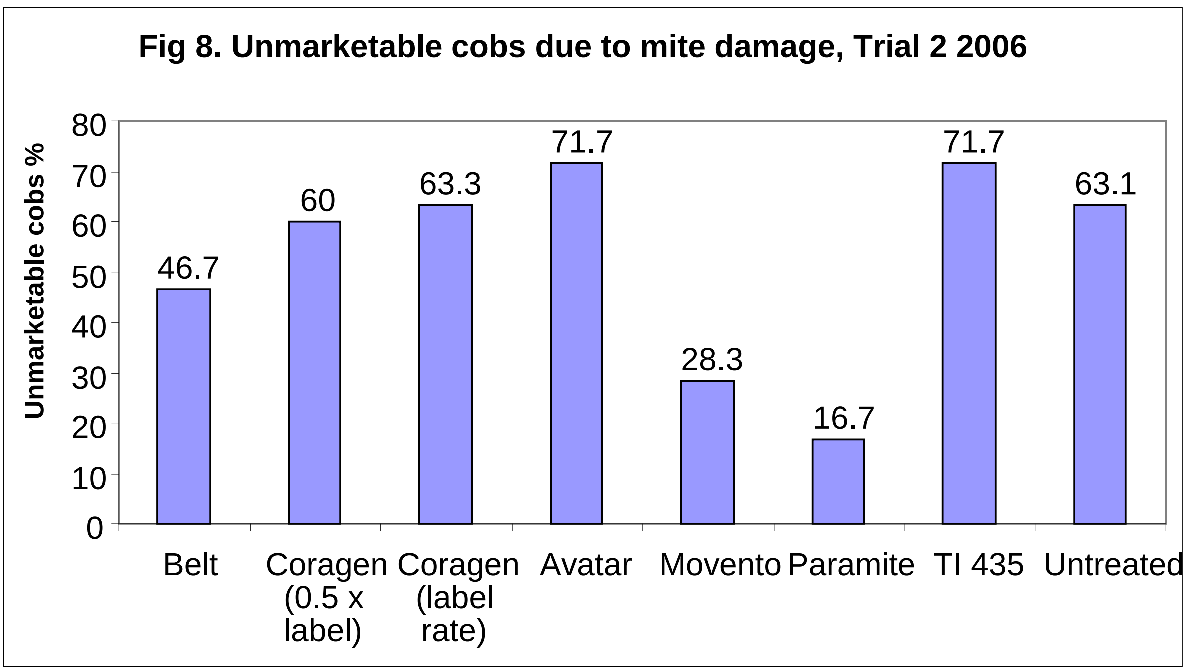


Fig 8. Unmarketable cobs due to mite damage, Trial 2 2006
Unmarketable cobs %
80
70
60
50
40
30
20
10
0
46.7
60
63.3
71.7
28.3
16.7
71.7
63.1
Belt
Coragen (0.5 x label)
Coragen (label rate)
Avatar
Movento
Paramite
TI 435
Untreated

## 5.13 South Queensland – Soft Options - Results

Three trials were planted on the Gatton Research Station - 25th January and harvested on the 18th April 2006 using Hi-brix (formally H5); 7th September and harvested on the 4th December 2006 using Golden Sweet; and 6th February 2007 using Hi-Brix; to evaluate a range of insecticides for lepidopteran insects and sap sucking insect control, and to monitor the effects of insecticides on naturally occurring beneficials.

### a) Trial 1 - Results

*Thrips*. Thrips were the only sap sucking pest present in any numbers early in the crop life. Treatment SCSI-03a had a significant affect on thrips numbers with monitoring in the field and a final plant count 34 days after planting exhibiting less thrips numbers and improved quality of the plants as seen in Figures 9 and 10. 34 DAP the plants were rated 0-5 with the SCSI-03a exhibiting significantly better quality plants than the untreated control, 0.48 compared to 1.38 respectively.

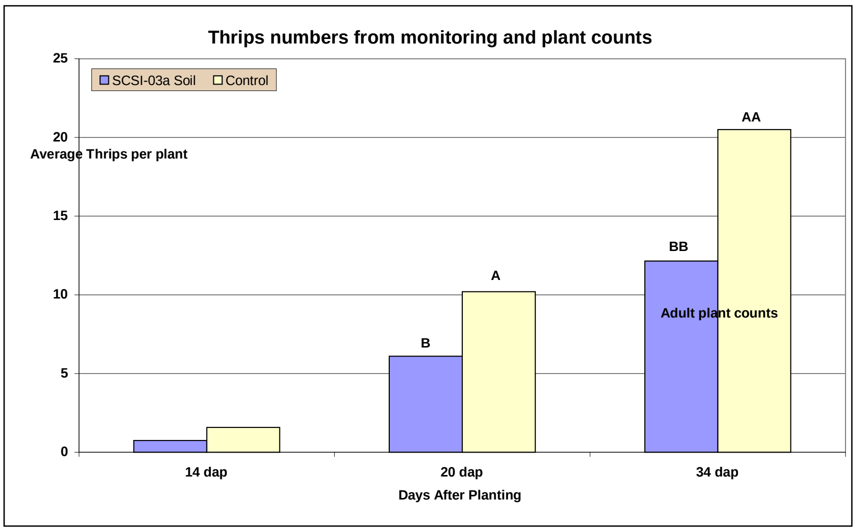



Figure 9. Thrips counts from direct field monitoring including the adult numbers from the whole plant 34 DAP.

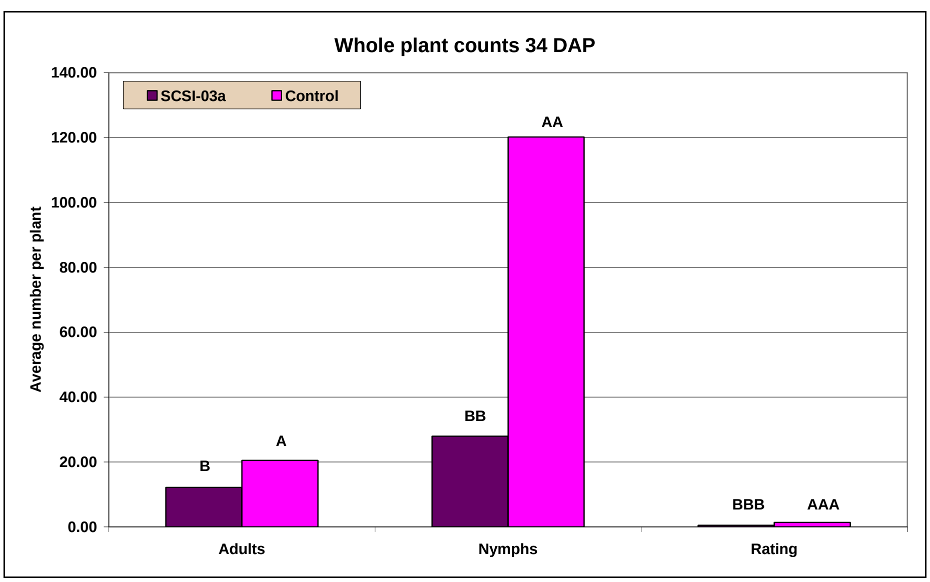



Figure 10. Thrips counts from the whole plant including both adults and nymphs as well as a rating on the plant symptoms 34 DAP.

The final plant count 34 DAP had significantly less adults and nymphs than the untreated control plants with the control having as many as 120 nymphs compared to nearly 28 nymphs in the SCSI-03a plants.

At harvest all insecticidal treatments were better at controlling helicoverpa numbers than the unsprayed control as seen in Figure 11. The control treatment had over 2 larvae present in 10 cobs assessed while all treatments had no more that one larva in 20 cobs with the majority less than this, Avatar™ being the poorer performer of the insecticide treatments with one in 20 cobs. There was no significant difference between treatments for yellow peach moth control, Figure 12. This is most likely due to the relatively small numbers of larvae found in the crop and between treatments. However, SCLI-02 and the high rate of SCLI-01 had less larvae present in the cob than the control treatment. The SCLI-03 treatment had more larvae present that all other treatments including the unsprayed control. The presence of sorghum head caterpillars, Figure 5, was quite variable between treatments with more than 10 larvae found in 10 cobs for the SCLI-03 treatment to a low of less than 2 larvae in 10 cobs for the high rate of SCLI-02 treatment. The high rate of SCLI-02 was the only treatment that was significantly better than the unsprayed control treatment at reducing caterpillar numbers. With the exception of SCLI-03, all other insecticidal treatments did show a reduction in caterpillar activity compared to the control treatment although these were not significant.

The damage to the cobs was significantly less in all treatments except the SCLI-03 treatments compared to the unsprayed control, Figure 14. The control plots had up to 25% damage to the cobs where as the best treatments were SCLI-02 and the high rate of SCLI-01 with no damage found on the tips or sides of the cobs.

Aphid numbers soon after harvest were prevalent in the unsprayed control plots and the SCLI-03 plots compared to the SCSI-01 and the SCSI-03a plots. Using a rating scale to assess numbers of aphids showed almost no aphids in the SCSI-01 and SCSI-03a plots where as the control and SCLI-03 plots had on average close to 50 aphids per plant, Figure 15. The field counts had some plants in these 2 treatments with more than 500 aphids on the leaves.

Beneficial insect numbers were not significantly different between treatments as shown in Table 53. The most prevalent were spiders, pirate bug and the trichogramma egg parasitoid.

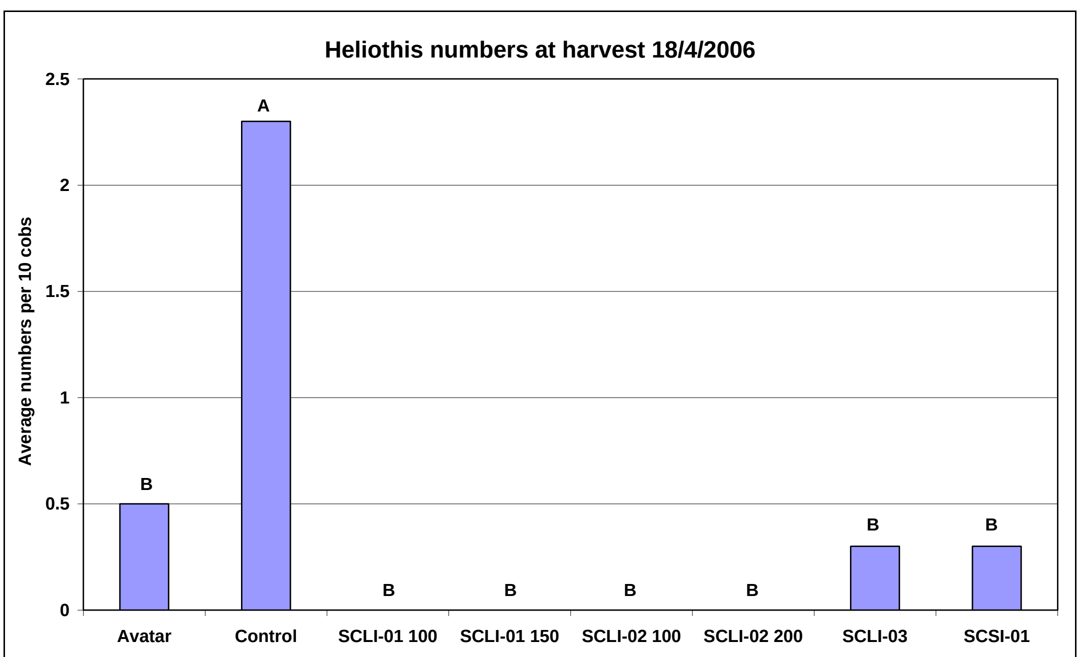



Figure 11. *Helicoverpa* numbers found in 10 cobs at harvest on the 18th April 2006.

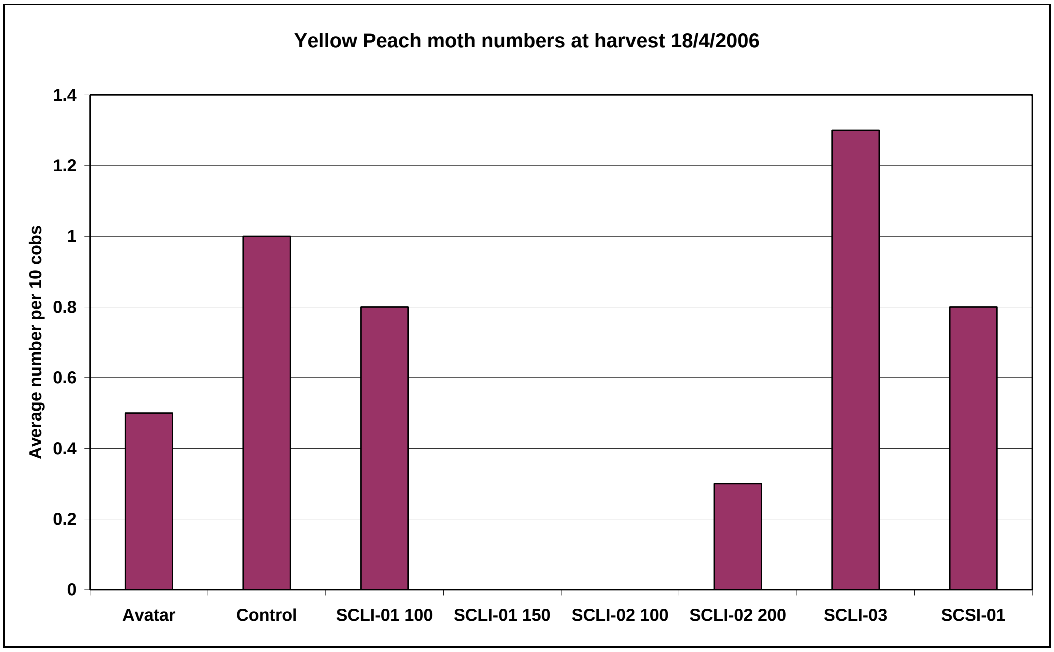



Figure 12. Yellow peach moths numbers found in 10 cobs at harvest on the 18th April 2006.

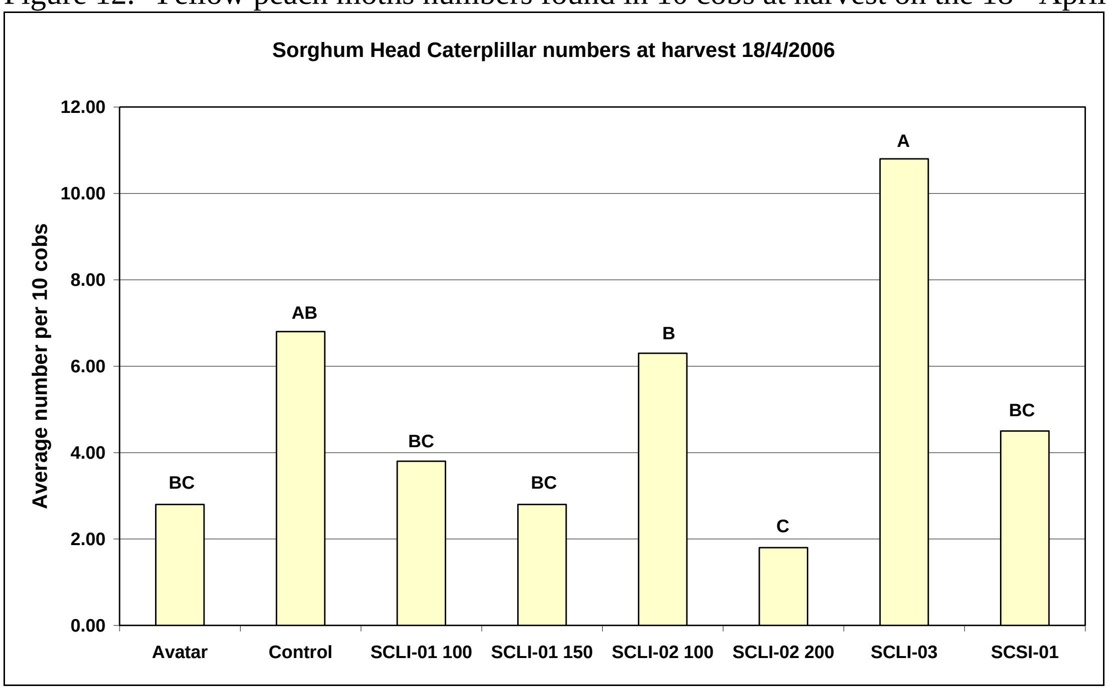



Figure 13. Sorghum head caterpillar numbers found on 10 cobs at harvest on the 18th April 2006.

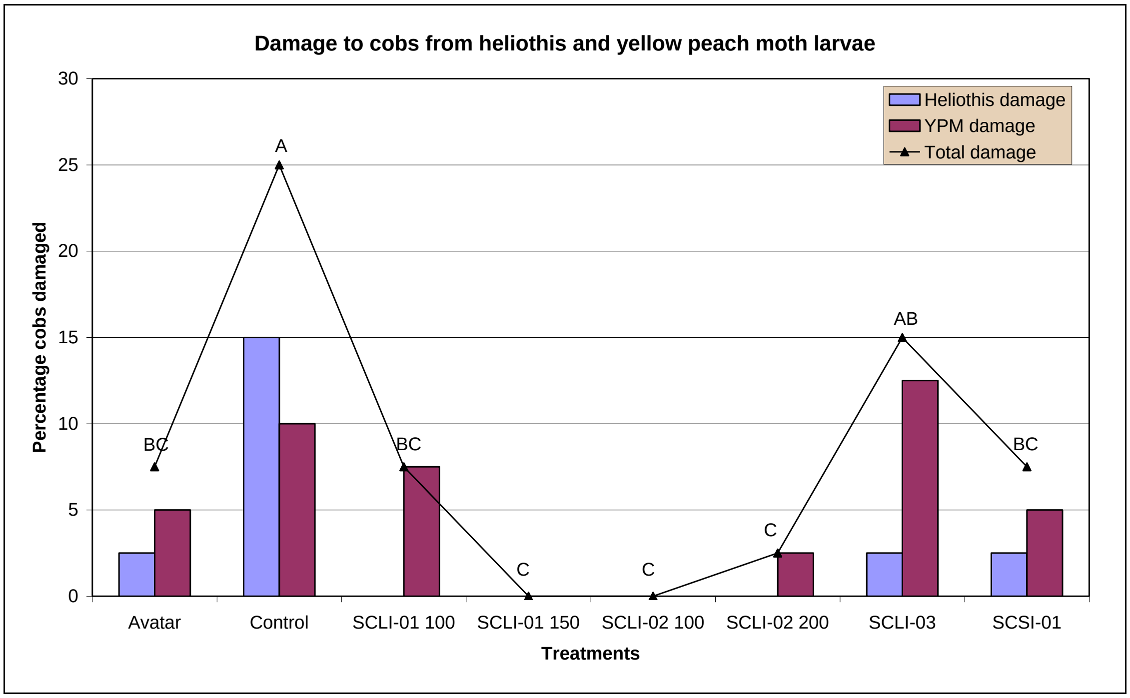



Figure 14. Percentage damage to cobs from helicoverpa and yellow peach moth activity found during harvest on the 18th April 2006 as the Gatton Research Station.

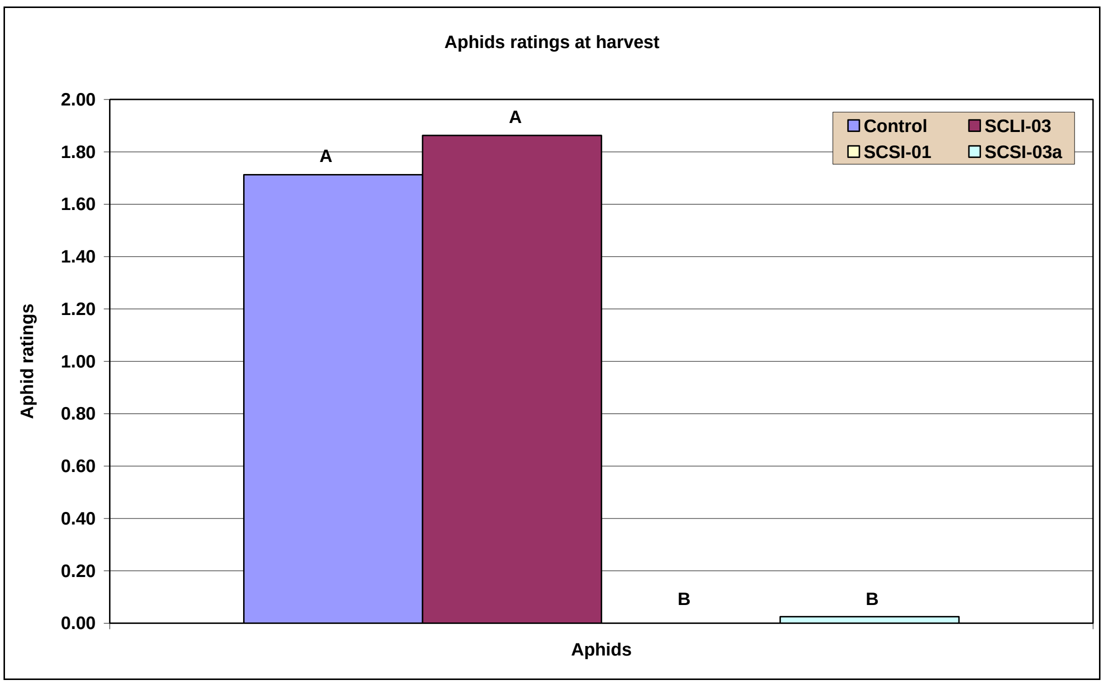



Figure 15. Rating of aphid incidence on the corn plants soon after harvest at the Gatton Research Station.

Table 53. Beneficial insect numbers trapped using yellow sticky traps placed at cob height within each treatment.

| Date | Treatments | Spiders | Trichogramma | Pirate bug |
|---|---|---|---|---|
| 30/3/2007 | Avatar™ | 0.00 | 2.50 | 0.25 |
| | Control | 0.00 | 2.00 | 0.00 |
| | SCLI-01 100 | 0.00 | 3.00 | 0.00 |
| | SCLI-01 150 | 0.00 | 3.75 | 0.00 |
| | SCLI-02 100 | 0.25 | 3.25 | 0.50 |
| | SCLI-02 200 | 0.00 | 2.75 | 0.00 |
| | SCLI-03 | 0.00 | 4.25 | 0.00 |
| | SCSI-01 | 0.25 | 2.75 | 0.00 |
| 6/4/2007 | Avatar™ | 0 | 1 | 0.5 |
| | Control | 0 | 2.75 | 0.25 |
| | SCLI-01 100 | 0.25 | 3 | 0 |
| | SCLI-01 150 | 0.25 | 1.5 | 0.5 |
| | SCLI-02 100 | 0 | 1.75 | 0.25 |
| | SCLI-02 200 | 0.25 | 3.25 | 0.5 |
| | SCLI-03 | 0 | 1.5 | 0.5 |
| | SCSI-01 | 0 | 2.5 | 0.25 |
| 12/4/2007 | Avatar™ | 0.25 | 2.25 | 0 |
| | Control | 0.5 | 2.25 | 0.25 |
| | SCLI-01 100 | 0 | 2 | 0 |
| | SCLI-01 150 | 0 | 1 | 0.25 |
| | SCLI-02 100 | 0.25 | 1.5 | 0.25 |
| | SCLI-02 200 | 0.75 | 2.75 | 0.25 |
| | SCLI-03 | 0 | 3.5 | 0.5 |
| | SCSI-01 | 0 | 1.5 | 0 |

**b) Trial 2 - Results**

*Thrips*

The pre-plant applications of SCSI-03 and Confidor Guard™ significantly reduced the number of thrips found attacking the plants during the initial growing period of the crop. The effect of the 2 insecticides started to show some break down in efficacy after 33 D.A.P. (days after planting). Figure 16 shows the effect of these treatments on total thrips numbers with the untreated control plants reaching a high of over 45 thrips per plant while the insecticide treatments only had on average 2.6 thrips per plant. The majority of thrips at 33 D.A.P. were nymphs as seen in Figure 9 with just over 41 nymphs found on untreated plants and less than 1 thrips nymph on average on the insecticide treated plants. Adult thrips numbers remained less than 7 thrips on average being found on the plants in the unsprayed control plants and in most cases less than 3 adult thrips on average on the insecticide treated plants which was still a significant reduction in thrips activity as seen in Figure 18. The sudden drop in adult thrips numbers at 39 D.A.P. can not be explained as it would be expected that these numbers should have been higher as the counts before and after this time were significantly more than the insecticide treated plants.

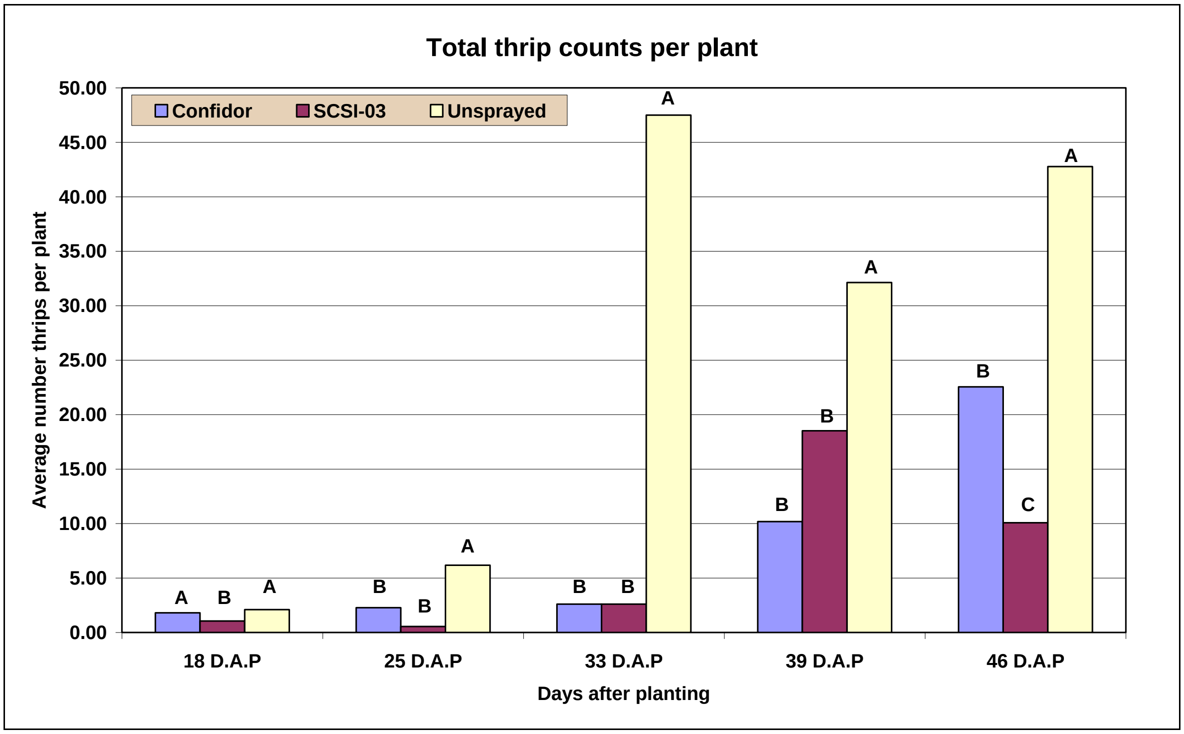



Figure 16. Total thrips counts per plant during the early vegetative growth stage of the crop.

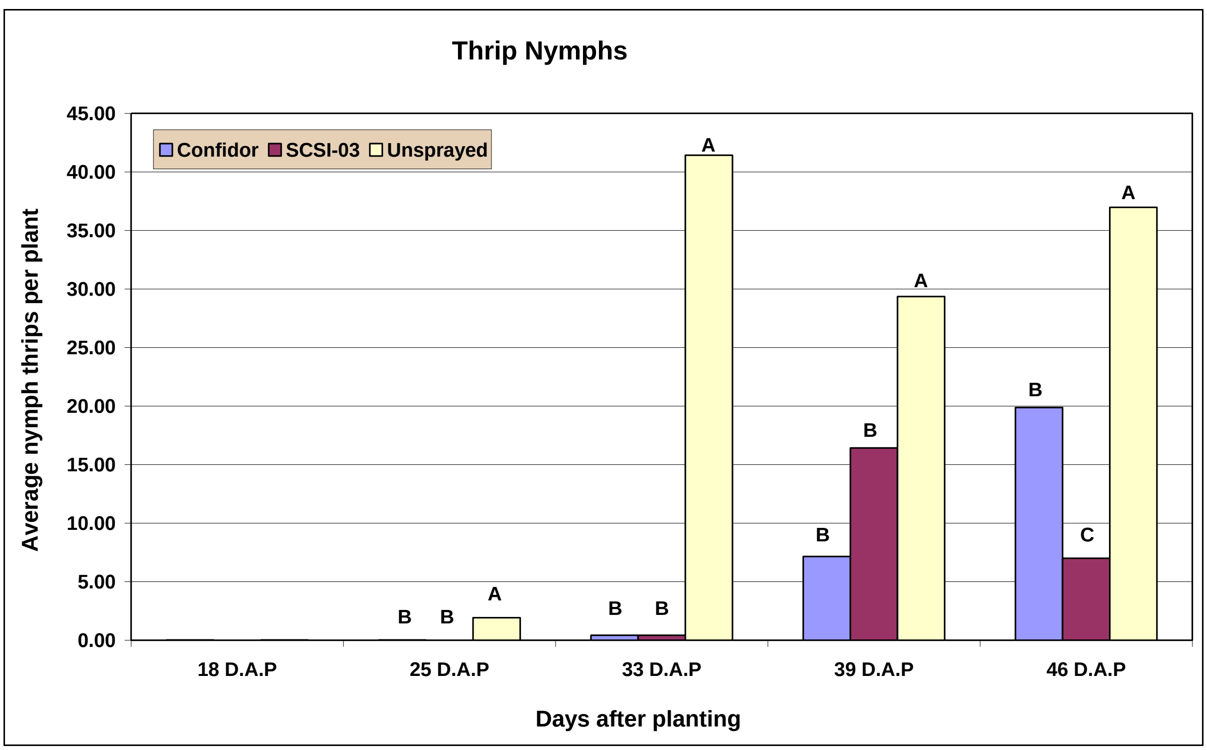



Figure 17. Total nymph counts per plant during the early vegetative growth stage of the crop.

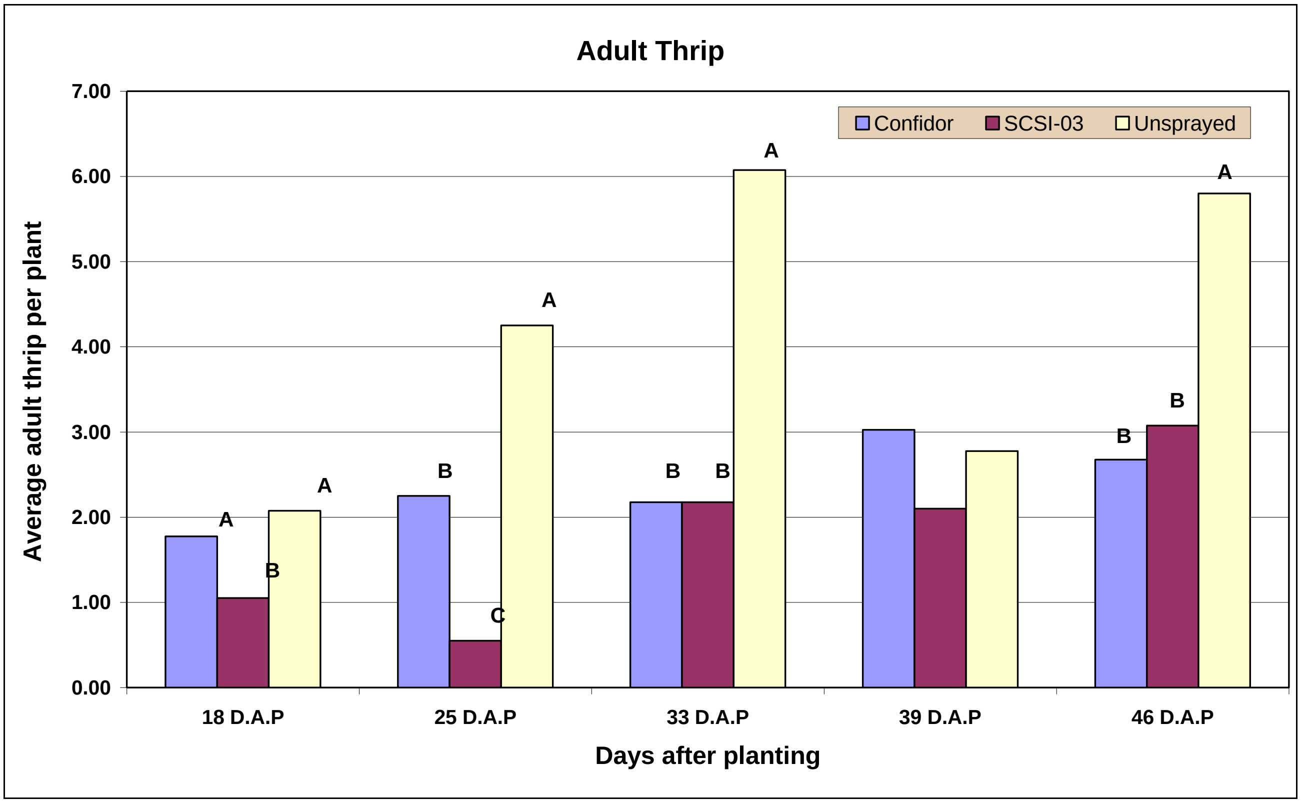



Figure 18. Total adult numbers per plant during the early vegetative growth stage of the crop.

*Helicoverpa*

Cob damage at harvest was significantly improved by using two new insecticides over the untreated control as shown in Figure 19. Three applications of SCLI-01 and SCLI-02 resulted in around two percent of the cobs damaged by helicoverpa. The higher than expected result of SCLI-01 100 can be explained by one replicate exhibiting the majority of this damage, which was on the western side of the trial site. This particular treatment was however not significantly different from the other three insecticide treatments that had very few damaged cobs. Avatar™ 15% damaged cobs and SCLI-03 11% damaged cobs, were not significantly different to the untreated control with 16% damaged cobs.

The majority of the damage was in the top 3cm of the cob as shown in Figure 18 with only a small number of cobs showing damage down to 6cm, 3 % damage in the Avatar and 2% damage in the untreated control treatments. None of the other treatments had any damage between 3cm and 6cm. There was more larvae present in those treatments that have performed significantly poorly in relation to the damaged cobs as seen in Figure 13. Although these were not significantly different from one another, SCLI-01 and the low rate of SCLI-02 still had fewer larvae present in the cobs at harvest.

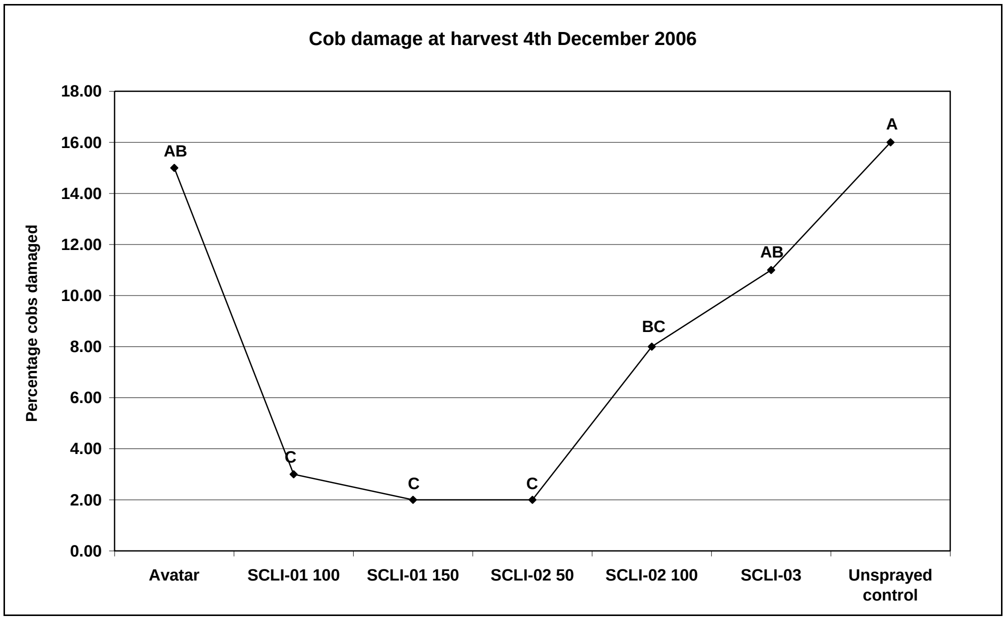



Figure 19. Percentage of cobs damaged primarily as a result of helicoverpa.

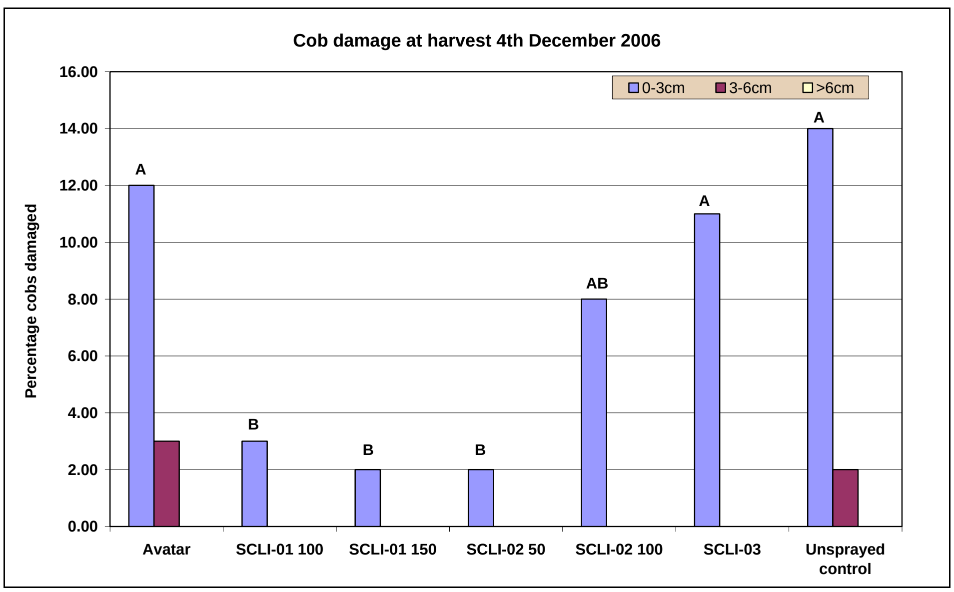



Figure 20. Damage to cobs at varying depths from the tip. The majority of damage was in top 3cm of the cobs.

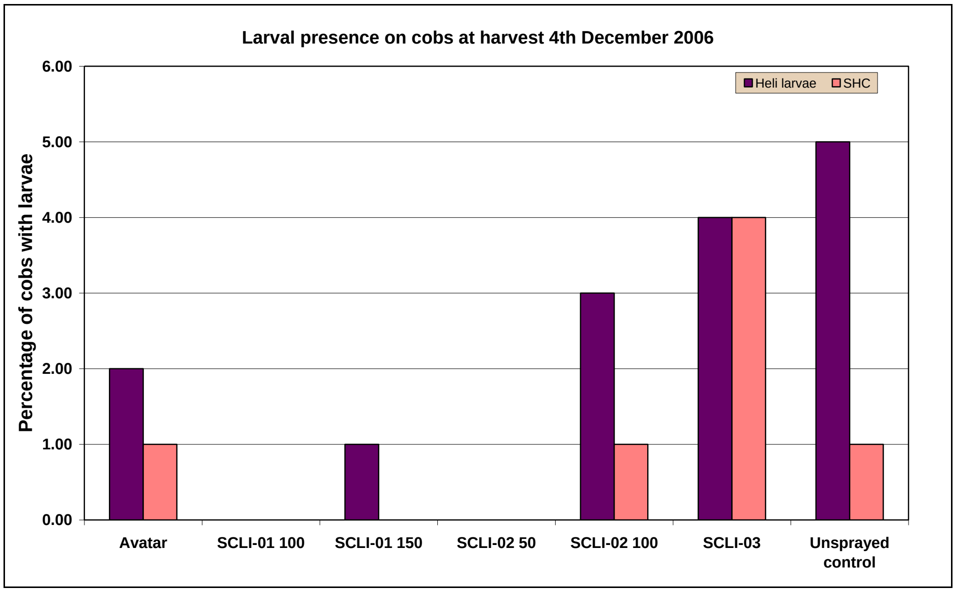



Figure 21. The type of larvae present in the cobs and the numbers found in each treatment.

Table 54. Direct field monitoring results of beneficial insects during sweet corn silking - Golden Sweet variety, Spring 2006.

| Date | Treatment | Lace wing | Spiders | Predatory bugs | Predatory beetles |
|---|---|---|---|---|---|
| 8/11/2006 | Avatar™ | 0.00 | 0.80 | 0.00 | 0.30 |
| | SCLI-02 100 | 0.30 | 0.80 | 0.50 | 0.50 |
| | SCLI-02 200 | 0.5 | 0.80 | 0.50 | 0.00 |
| | SCLI-01 100 | 1.5 | 0.30 | 0.80 | 0.00 |
| | SCLI-01 150 | 1.30 | 0.5 | 0.80 | 0.50 |
| | SCLI-03 | 0.5 | 0.30 | 0.50 | 0.00 |
| | Unsprayed control | 1.30 | 1.00 | 0.50 | 0.80 |
| | | | | | |
| 16/11/2006 | Avatar™ | 0.00 | 0.30 | 5.50 BC | 0 |
| | SCLI-02 100 | 0.00 | 0.30 | 4.75 BC | 0.5 |
| | SCLI-02 200 | 0.00 | 0.50 | 6.25 BC | 0.25 |
| | SCLI-01 100 | 0.50 | 0.30 | 6.75 BC | 0 |
| | SCLI-01 150 | 0.30 | 0.00 | 4.00 C | 0 |
| | SCLI-03 | 0.30 | 1.00 | 7.75 B | 0.5 |
| | Unsprayed control | 0.00 | 0.50 | 11.50 A | 0.75 |
| | | | | | |
| 24/11/2006 | Avatar™ | 0.00 | 1.00 | 8.5 | 0.25 C |
| | SCLI-02 100 | 0.00 | 0.80 | 8 | 0.75 BC |
| | SCLI-02 200 | 0.00 | 0.00 | 6.75 | 1.50 ABC |
| | SCLI-01 100 | 0.00 | 1.30 | 8 | 2.75 AB |
| | SCLI-01 150 | 0.00 | 1.80 | 8.75 | 3.50 A |
| | SCLI-03 | 0.30 | 0.50 | 8.5 | 1.00 BC |
| | Unsprayed control | 0.30 | 1.80 | 8.75 | 2.00 ABC |

Columns with the same letters are not significantly different from one another.
Predatory bugs = pirate bug, smudge bug, damsel bug, big-eyed bug, broken-backed bug, predatory shield bug, apple dimple bug,
Predatory beetles = the various ladybird beetles, red and blue beetles, small brown Anthicid beetle

*Beneficial insects*

The two methods for assessing beneficial insects in the field were inconclusive. Direct field monitoring for beneficial insects only found significant differences between treatments during peak silking on the 16$^{th}$ November 2006 and only for the predatory bugs. The following week this difference was not there, however there were differenced in the numbers of predatory beetles found on the plants as seen in table 2 below. Predatory bugs increased over time with all treatments whereas the predatory beetles increased overtime with the majority of the treatments. Avatar may have some effect on the beetle populations within sweet corn as shown in Figure 22 and Table 54.

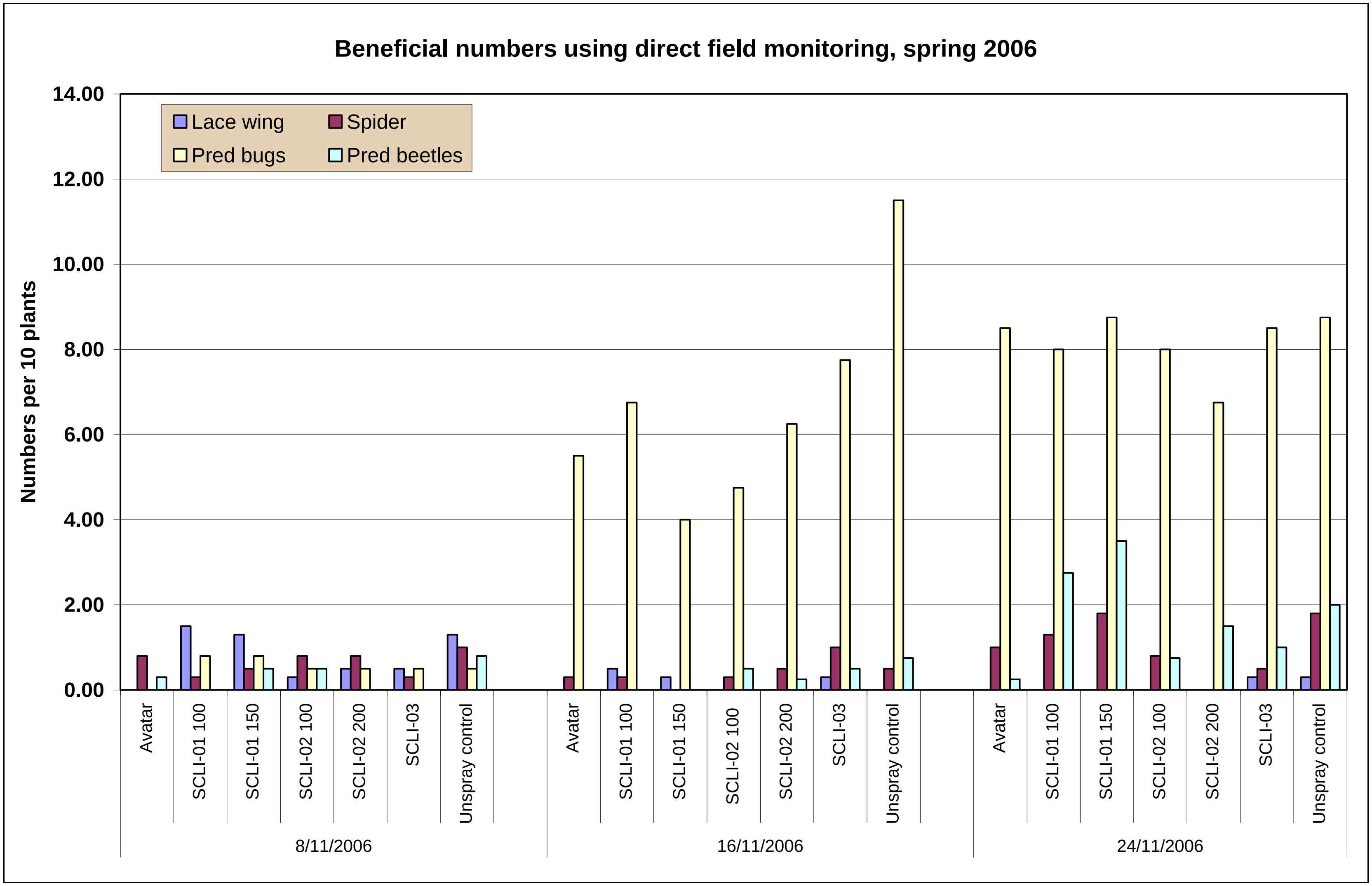



Figure 22. Numbers of beneficial insects found from early silking to 10 days before harvest or the brown silk stage. Monitoring carried out 3-4 days before the treatments were applied to the crop.

The use of yellow sticky traps showed very little differences between treatments during the silking period with predatory bugs showing the most significant differences on the 24th November 2006 with the unsprayed control plots harbouring significantly more beneficial bugs than a number of the insecticide treated plots as shown in Figure 23 and table 55.

Table 55. Yellow sticky trap counts after being left out for 24 hours for four weeks from early silking of sweet corn - Golden Sweet variety, Spring 2006.

| Date | Treatment | Trichogramma | Spiders | Lace wing | Predatory bugs | Predatory beetles |
|---|---|---|---|---|---|---|
| 8/11/2006 | Avatar™ | 4.00 | 0.50 | 0.5 | 1.75 | 0 |
| | Confidor™ | 3.00 | 0.00 | 0.50 | 1.25 | 0 |
| | SCLI-02 100 | 4.75 | 0.00 | 1.25 | 2.5 | 0 |
| | SCLI-02 200 | 4.25 | 0.25 | 0.25 | 2.75 | 0 |
| | SCLI-01 100 | 3.50 | 0.00 | 0.50 | 0.25 | 0 |
| | SCLI-01 150 | 5.50 | 0.00 | 0.75 | 1.75 | 0.5 |
| | SCLI-03 | 2.75 | 0.25 | 0.00 | 2.75 | 0 |
| | SCSI-03 | 4.75 | 0.00 | 0.00 | 0.5 | 0 |
| | Unsprayed control | 7.50 | 0.00 | 0.75 | 6.5 | 0 |
| | | | | | | |
| 15/11/2006 | Avatar™ | 2.25 | 0.00 | 0.25 B | 0.5 | 0 |
| | Confidor™ | 2.5 | 0.50 | 0.25 B | 0.5 | 0 |
| | SCLI-02 100 | 1.25 | 0.00 | 0 B | 0.75 | 0 |
| | SCLI-02 200 | 1.75 | 0.00 | 0.75 A | 0 | 0 |
| | SCLI-01 100 | 0.50 | 0.00 | 0 B | 0.25 | 0 |
| | SCLI-01 150 | 1.50 | 0.25 | 0.25 B | 0.75 | 0 |
| | SCLI-03 | 0.50 | 0.00 | 0 B | 0.5 | 0 |
| | SCSI-03 | 2.75 | 0.00 | 0 B | 0 | 0 |
| | Unsprayed control | 2.00 | 0.25 | 0 B | 0.75 | 0 |
| | | | | | | |
| 24/11/2006 | Avatar™ | 1.25 | 0.00 | 0.00 | 0 D | 0 |
| | Confidor™ | 1.50 | 0.00 | 0.00 | 1.75 ABCD | 0 |
| | SCLI-02 100 | 1.50 | 0.50 | 0.00 | 1 BCD | 0 |
| | SCLI-02 200 | 4.00 | 0.25 | 0.00 | 0.5 CD | 0 |
| | SCLI-01 100 | 1.50 | 0.25 | 0.00 | 2.5 AB | 0 |
| | SCLI-01 150 | 1.50 | 0.00 | 0.00 | 2.75 AB | 0.25 |
| | SCLI-03 | 1.25 | 0.25 | 0.25 | 2 ABC | 0 |
| | SCSI-03 | 2.00 | 0.00 | 0.00 | 1 BCD | 0 |
| | Unsprayed control | 2.00 | 0.00 | 0.50 | 3.5 A | 0 |
| | | | | | | |
| 30/11/2006 | Avatar™ | 0.00 | 0.00 | 0.25 | 0.5 | 0 |
| | Confidor™ | 0.50 | 0.25 | 0.25 | 0.75 | 0 |
| | SCLI-02 100 | 0.25 | 0.00 | 0.00 | 1.5 | 0 |
| | SCLI-02 200 | 0.00 | 0.25 | 0.25 | 1 | 0 |
| | SCLI-01 100 | 0.25 | 0.00 | 0.75 | 2 | 0 |
| | SCLI-01 150 | 0.00 | 0.25 | 0.25 | 1.75 | 0 |
| | SCLI-03 | 0.00 | 0.00 | 0.75 | 0.25 | 0 |
| | SCSI-03 | 0.25 | 0.00 | 0.00 | 0 | 0 |
| | Unsprayed control | 0.00 | 0.00 | 0.50 | 0.5 | 0 |

Columns with the same letters are not significantly different from one another.
Predatory bugs = pirate bug, smudge bug, damsel bug, big-eyed bug, broken-backed bug, predatory shield bug, apple dimple bug,
Predatory beetles = the various ladybird beetles, red and blue beetles, small brown Anthicid beetle

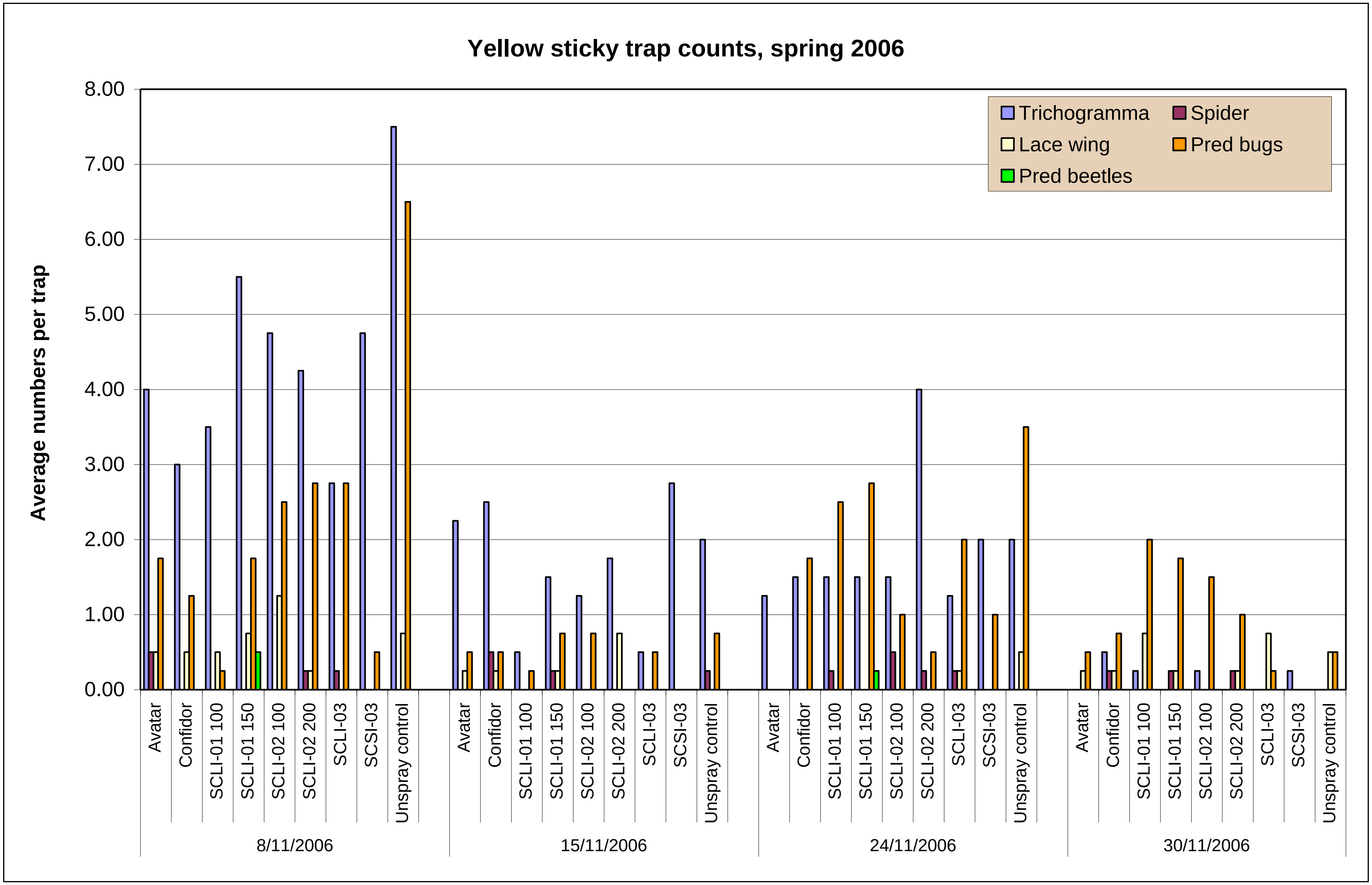



Figure 23. Numbers of beneficial insects found on yellow sticky traps placed in the crop at cob height and left there for 24 hours. Cards used during the silking period only.

### c) Trial 3 - Results

***Sowing to silking***

Thrips were the main sap sucking pest present early in the crop (13 to 34 DAS), reaching an average of 26 larvae per plant in the unsprayed control 27 DAS (Table 56). SCSI-03b was the most effective of the soil applied chemicals for thrips control, remaining effective against larval thrips until 34 DAS. Confidor Guard™ and Actara™ successfully controlled larval thrips until 27 DAS. Soil applied SCSI-02 was the least effective treatment as the number of larval thrips had increased significantly by 27 DAS and had increased to above that found in the control at 34 DAS.

Table 56. Mean densities (number/plant) of adult and larval thrips. Treatment means in the same column sharing a common letter are not significantly different (LSD test at $P = 0.05$). Numbers significantly lower than the control are highlighted in bold.

| Treatment | 13 DAS (19/2/07) | | 20 DAS (26/2/07) | | 27 DAS (5/3/07) | | 34 DAS (12/3/07) | |
|---|---|---|---|---|---|---|---|---|
| | Adults | Larvae | Adults | Larvae | Adults | Larvae | Adults | Larvae |
| Unsprayed control | 3.3 | Nil | 5.8 a | 9.0 a | 6.0 a | 25.7 a | 9.7 | 18.4 b |
| Actara™ | 2.4 | Nil | **1.6 b** | **0.2 b** | 4.2 ab | **3.7 b** | 6.5 | 19.8 b |
| Confidor Guard™ | 3.1 | Nil | **2.0 b** | **0 b** | **2.5 b** | **0.7 b** | 7.8 | 10.6 bc |
| SCSI-02 | 3.3 | Nil | **4.1 c** | **0.1 b** | 5.9 a | 16.6 a | 8.6 | 38.7 a |
| SCSI-03b | 2.8 | Nil | **1.3 b** | **0 b** | **1.4 b** | **0.6 b** | 7.2 | **6.5 c** |

Jassids, aphids and leafhoppers were also present, but in low numbers early in the crop (Table 57). There was a significant effect of treatment on aphids at 20 DAS, with fewer in the Actara™ and SCSI-03b treatments compared to the control ($P < 0.05$). There was no significant effect of treatment on jassids at any of the assessment dates ($P > 0.05$). Leafhopper numbers were too low to allow analysis.

The main beneficial species recorded during the early stages of the crop were spiders and ladybirds (predominantly *Hippodamia variegata*, but also the transverse ladybird *Coccinella transversalis*) (Table 58). Low numbers of predatory bugs (brown smudge bugs *Deraeocoris signatus* and pirate bugs *Orius* spp.) were recorded at 27 DAS. In most instances numbers were too low to allow statistical analysis, however where data were analysed no significant effects of treatment were found.

Table 57. Mean densities (number/10 plants) of jassids, aphids and leafhoppers. Treatment means in the same column sharing a common letter are not significantly different (LSD test at $P$ = 0.05). Numbers significantly lower than the control are highlighted in bold.

| Pest | Treatment | 13 DAS (19/02/07) | 20 DAS (26/02/07) | 27 DAS (05/03/07) |
|---|---|---|---|---|
| Jassids | Unsprayed control | 0.5 | 2.8 | 9.5 |
| | Actara™ | 0.5 | 1.3 | 5.3 |
| | Confidor Guard™ | 0.5 | 1.3 | 6.0 |
| | SCSI-02 | 1.0 | 0.3 | 11.8 |
| | SCSI-03b | 0.8 | 1.3 | 5.3 |
| Aphids | Unsprayed control | 0 | 1.2 ab | 1.8 |
| | Actara™ | 0.3 | **0 c** | 1.0 |
| | Confidor Guard™ | 0.3 | 0.2 bc | 2.8 |
| | SCSI-02 | 0 | 1.5 a | 0 |
| | SCSI-03b | 0 | **0 c** | 1.5 |
| Leafhoppers | Unsprayed control | 0 | 0 | 1.0 |
| | Actara™ | 0 | 0 | 0 |
| | Confidor Guard™ | 0 | 0 | 0 |
| | SCSI-02 | 0.3 | 0 | 0.3 |
| | SCSI-03b | 0 | 0 | 0 |

Table 58. Mean densities (number/10 plants) of beneficial insects

| Beneficial | Treatment | 13 DAS (19/02/07) | 20 DAS (26/02/07) | 27 DAS (05/03/07) |
|---|---|---|---|---|
| Spiders | Unsprayed control | 1.3 | 0.5 | 2.0 |
| | Actara™ | 0.8 | 1.0 | 2.0 |
| | Confidor Guard™ | 1.3 | 0 | 1.3 |
| | SCSI-02 | 1.3 | 1.3 | 1.5 |
| | SCSI-03b | 0.8 | 1.0 | 1.3 |
| Ladybirds | Unsprayed control | 0 | 0 | 1.5 |
| | Actara™ | 0.3 | 0 | 1.3 |
| | Confidor Guard™ | 0.3 | 0 | 1.8 |
| | SCSI-02 | 0 | 0 | 0.8 |
| | SCSI-03b | 0 | 0 | 0.3 |
| Predatory bugs | Unsprayed control | N/A | N/A | 0.5 |
| | Actara™ | N/A | N/A | 0.3 |
| | Confidor Guard™ | N/A | N/A | 0 |
| | SCSI-02 | N/A | N/A | 0 |
| | SCSI-03b | N/A | N/A | 0 |

***Silking to harvest***

*Helicoverpa* were monitored over the latter part of the crop life ($4^{th}$ to $26^{th}$ April; 57 to 79 DAS) (Table 59). There was no significant effect of treatment on the number of eggs at any of the assessment dates ($P$ > 0.05). Larval numbers were generally too low to allow statistical analysis, however where data were analysed (79 DAS) no significant effect of treatment was found, although SCSI-01 and dimethoate harboured the greatest number of larvae.

Table 59. Mean densities (number/10 plants) of helicoverpa eggs (white, brown and parasitised) and larvae (all sizes)

| Treatment | 57 DAS (04/04/07) | | 65 DAS (12/04/07) | | 71 DAS (18/04/07) | | 79 DAS (26/04/07) | |
|---|---|---|---|---|---|---|---|---|
| | eggs | larvae | eggs | larvae | eggs | larvae | eggs | larvae |
| Control | 14.5 | 0 | 8.0 | 0 | 2.3 | 0.8 | 3.3 | 0.3 |
| Actara™ | 11.5 | 0 | 13.5 | 0.3 | 1.0 | 0.5 | 3.3 | 0.8 |
| Confidor Guard™ | 9.5 | 0 | 7.8 | 0.5 | 4.0 | 2.8 | 5.5 | 1.0 |
| SCSI-02 Soil | 10.0 | 0 | 9.8 | 0.3 | 1.0 | 0.5 | 2.5 | 0.8 |
| SCSI-03b | 10.5 | 0 | 10.5 | 0.5 | 2.8 | 0.5 | 2.5 | 1.3 |
| Dimethoate™ | 8.3 | 0 | 6.3 | 0 | 5.5 | 1.0 | 4.0 | 4.0 |
| SCSI-01 | 10.3 | 0 | 5.8 | 0 | 2.3 | 0.5 | 3.5 | 4.0 |
| SCSI-02 Foliar | 14.8 | 0 | 4.0 | 0 | 4.0 | 0 | 3.0 | 0.3 |

Other pest species recorded over the latter part of the trial were aphids, mites and flea beetles (Table 60). There was a statistically significant effect of treatment on numbers of aphids at 71 DAS, with significantly fewer aphids in the Confidor Guard™, SCSI-01, dimethoate and SCSI-03b treatments compared to the control ($P < 0.05$). However, a statistically significant effect was not detected at the following assessment (79 DAS), despite the fact that there were substantially higher numbers in the control than the insecticide treatments. This may have been due to the very patchy distribution of aphids within the plots.

Numbers of flea beetles in several treatments (Confidor Guard™, SCSI-03b, SCSI-01 and dimethoate) were consistently lower than the control. However, this difference was not statistically significant ($P > 0.05$). Likewise, there was no significant effect of treatment on numbers of mites at any assessment date ($P > 0.05$), although by 79 DAS there were more mites in many of the insecticide treatments (Confidor Guard™, Actara™, dimethoate, SCSI-03b, SCSI-02 foliar) compared to the control.

Numbers of sorghum head caterpillar (SHC) were recorded at the final assessment (26th April). Although there were fewer larvae in some of the treatments compared to the control (Confidor Guard™, SCSI-02 foliar, SCSI-01), this was not a significant difference ($P > 0.05$).

Table 60. Mean densities of aphids, flea beetles, sorghum head caterpillar (number/10 plants) and mites (average rating: 1 = small area, 2 = 2 leaves infected, 3 = 3 or more leaves infected). Treatment means in the same column sharing a common letter are not significantly different (LSD test at *P* = 0.05). Numbers significantly lower than the control are highlighted in bold.

| Pest | Treatment | 57 DAS (04/04/07) | 65 DAS (12/04/07) | 71 DAS (18/04/07) | 79 DAS (26/04/07) |
|---|---|---|---|---|---|
| Aphids | Unsprayed control | 15.3 | 0 | 19.2 a | 111.5 |
| | Actara™ | 2.5 | 0.3 | 3.5 ab | 4.3 |
| | Confidor Guard™ | 1.3 | 13.0 | **0.6 b** | 0.3 |
| | SCSI-02 soil | 16.5 | 1.0 | 3.2 ab | 40.0 |
| | SCSI-03b | 0.8 | 0 | **0 b** | 5.3 |
| | Dimethoate™ | 10.3 | 0.5 | **0 b** | 0.3 |
| | SCSI-01 | 11.8 | 1.5 | **0.3 b** | 0.8 |
| | SCSI-02 foliar | 19.3 | 38.0 | 15.9 a | 43.0 |
| Mites | Unsprayed control | 0.2 | 0.3 | 0.8 | 0.8 |
| | Actara™ | 0.2 | 0.2 | 0.9 | 1.6 |
| | Confidor Guard™ | 0.2 | 0.5 | 1.0 | 1.9 |
| | SCSI-02 soil | 0.1 | 0.1 | 0.6 | 0.7 |
| | SCSI-03b | 0.1 | 0.3 | 1.0 | 1.5 |
| | Dimethoate™ | 0.2 | 0.3 | 0.9 | 1.5 |
| | SCSI-01 | 0.3 | 0.4 | 0.6 | 0.9 |
| | SCSI-02 foliar | 0.1 | 0.4 | 0.3 | 1.4 |
| Flea beetles | Unsprayed control | 6.8 | 1.8 | 2.3 | 2.5 |
| | Actara™ | 4.0 | 0.8 | 4.3 | 0.8 |
| | Confidor Guard™ | 5.3 | 1.3 | 1.5 | 0.3 |
| | SCSI-02 soil | 6.5 | 4.5 | 1.5 | 2 |
| | SCSI-03b | 5.0 | 1.3 | 0.5 | 0.3 |
| | Dimethoate™ | 5.5 | 0.8 | 0.8 | 0 |
| | SCSI-01 | 5.5 | 0.5 | 0 | 0.5 |
| | SCSI-02 foliar | 10.0 | 1.5 | 0.3 | 0.8 |
| SHC | Unsprayed control | - | - | - | 2.5 |
| | Actara™ | - | - | - | 1.3 |
| | Confidor Guard™ | - | - | - | 0.8 |
| | SCSI-02 soil | - | - | - | 2.8 |
| | SCSI-03b | - | - | - | 2.3 |
| | Dimethoate™ | - | - | - | 1.8 |
| | SCSI-01 | - | - | - | 0.5 |
| | SCSI-02 foliar | - | - | - | 0 |

Parasitism of helicoverpa eggs fluctuated over the course of the trial, with no consistent or statistically significant differences amongst treatments (Table 61).

Table 61. Mean number of parasitised (black) helicoverpa eggs per 10 plants (expressed as a percentage of the total number of helicoverpa eggs in brackets).

| Treatment | 57 DAS (04/04/07) | 65 DAS (12/04/07) | 71 DAS (18/04/07) | 79 DAS (26/04/07) |
|---|---|---|---|---|
| Unsprayed control | 0.5 (10.0) | 1.8 (28.6) | 1.5 (67.5 †) | 0.3 (12.5) |
| Actara™ | 0.3 (5.0) | 5.5 (30.0) | 0.3 (16.7 †) | 0.5 (10.0) |
| Confidor Guard™ | 0 (0) | 2.0 (31.2) | 1.3 (65.0) | 0.5 (33.3 †) |
| SCSI-02 soil | 0.8 (6.3) | 1.5 (24.7) | 0.8 (50.0 †) | 0.8 (25.0) |
| SCSI-03b | 0.3 (1.9) | 4.3 (29.5) | 1.5 (33.3 *) | 2.3 (94.4 *) |
| Dimethoate™ | 0 (0) | 0 (0 *) | 4.3 (80.3 *) | 1.5 (28.6 *) |
| SCSI-01 | 0.3 (3.6) | 0.5 (9.5 *) | 0.8 (20.0 *) | 1.5 (33.3) |
| SCSI-02 foliar | 0 (0) | 0.8 (25.0 *) | 2.3 (61.3) | 0.8 (37.5) |

When calculating percentages replicates with no eggs were omitted:
* average of 3 replicates
† Average of 2 replicates

Other beneficials recorded over the latter part of the trial were: spiders, ladybirds (3 banded, white collared, transverse, minute two-spotted) and pirate bugs. Lacewings, predatory bugs (smudge bug, big eyed bug, brokenbacked bug), predatory beetles (e.g. red and blue beetle) and predatory thrips were also observed occasionally; these were grouped into 'other predators' for the purpose of analysis (Table 62).

Dimethoate had an adverse effect on the majority of the beneficial species, and this was found to be statistically significant on several occasions, particularly towards the end of the trial (Table 12). This may at least partially explain the higher numbers of helicoverpa larvae observed in the dimethoate treatment at 79 DAS. Numbers of beneficials were also significantly lower in the majority of the other insecticide treatments compared to the control at one or more assessments, although this was generally not consistent across assessments or species.

Numbers of ladybirds appeared to be particularly affected by treatment towards the end of the trial, although results were not subjected to statistical analysis as numbers were too low.

Table 62. Mean densities (number/10 plants) of beneficial insects. For each beneficial group, treatment means in the same column sharing a common letter are not significantly different (LSD test at *P* = 0.05). Numbers significantly lower than the control are highlighted in bold.

| Beneficial | Treatment | 57 DAS (04/04/07) | 65 DAS (12/04/07) | 71 DAS (18/04/07) | 79 DAS (26/04/07) |
|---|---|---|---|---|---|
| Spiders | Unsprayed control | 2.0 | 1.5 | 2.8 a | 1.8 ab |
| | Actara™ | 1.0 | 2.8 | 1.2 ab | 2.8 ab |
| | Confidor Guard™ | 2.8 | 3.8 | 2.1 a | 2.9 ab |
| | SCSI-02 Soil | 2.5 | 2.5 | 2.8 a | 4.1 a |
| | SCSI-03b | 1.3 | 1.5 | 2.9 a | 3.6 a |
| | Dimethoate™ | 4.3 | 1.0 | **0.2 b** | **0.2 c** |
| | SCSI-01 | 2.5 | 2.3 | **0.4 b** | 0.9 bc |
| | SCSI-02 Foliar | 2.8 | 1.0 | **0.4 b** | 1.0 bc |
| Ladybirds | Unsprayed control | 1.5 | 0.5 | 0 | 7.8 |
| | Actara™ | 0.3 | 0.5 | 0 | 1.8 |
| | Confidor Guard™ | 0 | 0 | 0 | 1.3 |
| | SCSI-02 Soil | 0.3 | 0 | 1.0 | 0 |
| | SCSI-03b | 0.3 | 0.3 | 0 | 0.3 |
| | Dimethoate™ | 1.8 | 0.5 | 0.3 | 0.3 |
| | SCSI-01 | 1.8 | 0.8 | 0 | 0.8 |
| | SCSI-02 Foliar | 0.5 | 0.8 | 0 | 0.3 |
| Pirate bugs | Unsprayed control | 7.0 | 12.5 | 8.8 | 10.1 ab |
| | Actara™ | 7.3 | 17.8 | 9.3 | 12.7 a |
| | Confidor Guard™ | 3.0 | 10.5 | 10.8 | 8.1 ab |
| | SCSI-02 Soil | 6.5 | 8.8 | 7.8 | 7.6 ab |
| | SCSI-03b | 0.8 | 10.8 | 10.5 | 10.9 ab |
| | Dimethoate™ | 6.8 | 4.0 | 3.3 | **0.7 c** |
| | SCSI-01 | 7.0 | 9.3 | 9.0 | 4.8 b |
| | SCSI-02 Foliar | 3.8 | 7.0 | 11.0 | 8.4 ab |
| Others | Unsprayed control | 2.3 ab | 5.8 a | 4.0 | 3.7 ab |
| | Actara™ | 1.0 bc | **2.0 bcd** | 1.8 | 1.6 bc |
| | Confidor Guard™ | **0.3 c** | 3.7 abc | 4.8 | **0.7 cd** |
| | SCSI-02 Soil | 1.3 abc | 4.1 ab | 4.8 | 6.1 a |
| | SCSI-03b | 1.0 bc | **1.8 cde** | 0.8 | **0.4 cd** |
| | Dimethoate™ | 3.0 a | **0.7 e** | 1.0 | **0 d** |
| | SCSI-01 | 2.5 ab | **1.2 de** | 2.5 | 3.1 ab |
| | SCSI-02 Foliar | 3.0 a | 3.9 ab | 2.0 | 3.6 ab |

Figures 24 to 27. Proportions of each group of beneficial organism

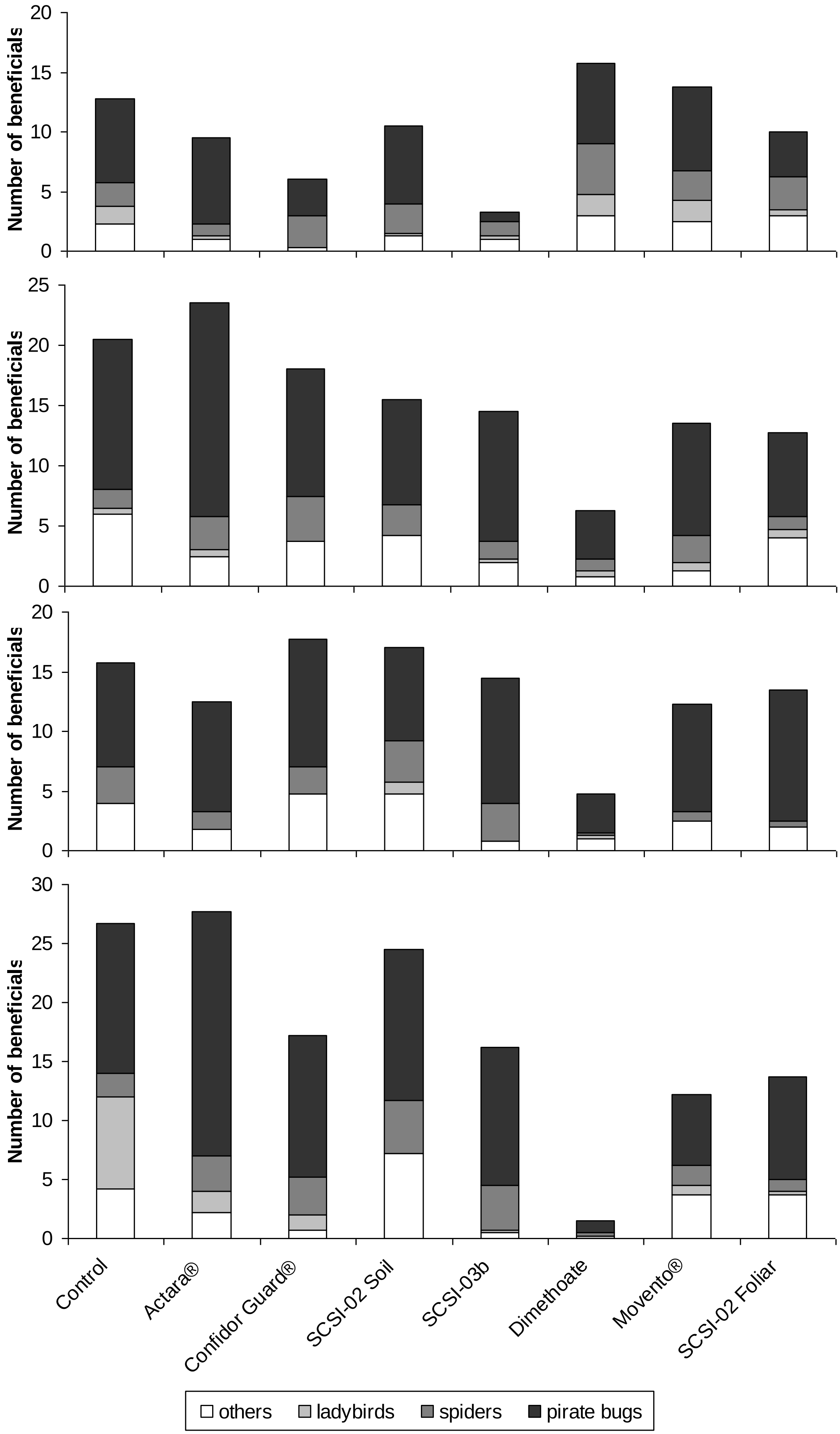



Fig.24 57 DAS

Fig.25 65 DAS

Fig.26 71 DAS

Fig.27 79 DAS

***Sticky traps***
Sticky traps were used as an additional sampling technique from silking to harvest (Table 63). Treatments were found to have a significant effect on numbers of trapped thrips at 71 DAS, with significantly fewer thrips in the Confidor Guard™, dimethoate and SCSI-02 foliar treatments compared to the control. Although thrips numbers were still low in these three insecticide treatments at the following assessment (79 DAS) the control population had declined, and no significant differences amongst treatments were detected. Dimethoate also had a significant effect on numbers of trapped jassids at the 79 DAS assessment only. Too few leafhoppers, flea beetles and aphids were trapped to allow statistical analysis.

There was no effect of treatment on the number of trichogramma wasps caught on the sticky traps (Table 64). Small numbers of other beneficial species were also trapped, summed for the purpose of analysis: pirate bug, spider, tachinid flies, predatory beetle, predatory thrips, transverse ladybird beetle, 3 banded ladybird beetle, black mirid and brown smudge bug. At 65 DAS there were significantly more of these other beneficials trapped in the control treatment than any other treatment except Confidor Guard™. Numbers were too low to allow analysis at 71 or 79 DAS.

Table 63. Mean numbers of pest insects trapped on yellow sticky traps. Treatment means in the same column sharing a common letter are not significantly different (LSD test at *P* = 0.05). Numbers significantly lower than the control are highlighted in bold.

| Pest | Treatment | 57 DAS (04/04/07) | 65 DAS (12/04/07) | 71 DAS (18/04/07) | 79 DAS (26/04/07) |
|---|---|---|---|---|---|
| Jassids | Unsprayed control | 8.0 | 4.3 | 5.5 | 8.7 ab |
| | Actara™ | 8.0 | 4.5 | 3.5 | 13.3 a |
| | Confidor Guard™ | 7.5 | 2.5 | 4.0 | 8.6 ab |
| | SCSI-02 soil | 5.0 | 6.0 | 6.0 | 9.7 ab |
| | SCSI-03b | 4.3 | 2.3 | 3.0 | 6.4 bc |
| | Dimethoate™ | 9.8 | 3.3 | 3.5 | **4.1 c** |
| | SCSI-01 | 12.3 | 3.0 | 5.5 | 10.3 ab |
| | SCSI-02 foliar | 12.5 | 5.8 | 2.5 | 7.0 bc |
| Thrips | Unsprayed control | 4.5 | 2.3 | 12.5 a | 5.8 |
| | Actara™ | 3.8 | 2.5 | 5.9 abc | 5.5 |
| | Confidor Guard™ | 2.8 | 4.0 | **4.3 bc** | 2.3 |
| | SCSI-02 soil | 2.5 | 4.8 | 5.6 abc | 3.3 |
| | SCSI-03b | 4.3 | 2.0 | 7.4 ab | 7.8 |
| | Dimethoate™ | 5.0 | 1.3 | **1.8 cd** | 1.8 |
| | SCSI-01 | 2.5 | 3.8 | 5.7 abc | 3.0 |
| | SCSI-02 foliar | 2.8 | 2.0 | **1.0 d** | 1.3 |
| Leafhoppers | Unsprayed control | 0.5 | 0.5 | 0.3 | 0 |
| | Actara™ | 0 | 0 | 0.3 | 0.5 |
| | Confidor Guard™ | 0.3 | 0.8 | 0.5 | 0 |
| | SCSI-02 soil | 0 | 0.3 | 0 | 0.3 |
| | SCSI-03b | 0 | 0 | 0.3 | 0.5 |
| | Dimethoate™ | 0.3 | 0.3 | 0 | 0.3 |
| | SCSI-01 | 0 | 0 | 0.5 | 0 |
| | SCSI-02 foliar | 0.5 | 0 | 0.3 | 0.3 |
| Flea beetles | Unsprayed control | 1.3 | 1.0 | 0 | 0.5 |
| | Actara™ | 0.3 | 0 | 0 | 0 |
| | Confidor Guard™ | 1.0 | 0.3 | 0 | 0.3 |
| | SCSI-02 soil | 0.3 | 0.3 | 0 | 0.3 |
| | SCSI-03b | 0.3 | 0 | 0 | 0.3 |
| | Dimethoate™ | 1.3 | 0.3 | 0.3 | 0 |
| | SCSI-01 | 0.5 | 0.5 | 0 | 0.3 |
| | SCSI-02 foliar | 0.8 | 0 | 0 | 0 |
| Aphids | Unsprayed control | 0.8 | 0.3 | 0 | 0 |
| | Actara™ | 0 | 0 | 0 | 1.3 |
| | Confidor Guard™ | 0 | 0 | 0 | 0 |
| | SCSI-02 soil | 0 | 0.3 | 0 | 0 |
| | SCSI-03b | 0.3 | 0 | 0 | 0 |
| | Dimethoate™ | 0.3 | 0 | 0 | 0.3 |
| | SCSI-01 | 0.3 | 0 | 0 | 0 |
| | SCSI-02 foliar | 0.3 | 0.3 | 0 | 0.3 |

Table 64. Mean numbers of trichogramma and other beneficial insects trapped on yellow sticky traps. Treatment means in the same column sharing a common letter are not significantly different (LSD test at $P = 0.05$). Numbers significantly lower than the control are highlighted in bold.

| Beneficial | Treatment | 57 DAS (04/04/07) | 65 DAS (12/04/07) | 71 DAS (18/04/07) | 79 DAS (26/04/07) |
|---|---|---|---|---|---|
| trichogramma | Control | 1.8 | 0.3 | 1.8 | 1.5 |
| | Actara™ | 3.5 | 1.5 | 1.3 | 1.0 |
| | Confidor Guard™ | 1.8 | 1.0 | 1.0 | 1.8 |
| | SCSI-02 Soil | 2.0 | 1.5 | 1.0 | 0.5 |
| | SCSI-03b | 0.8 | 0.5 | 1.0 | 0.8 |
| | Dimethoate™ | 3.3 | 1.8 | 2.5 | 2.8 |
| | SCSI-01 | 1.8 | 0.8 | 2.3 | 1.8 |
| | SCSI-02 Foliar | 4.3 | 1.5 | 2.3 | 1.3 |
| Other beneficials | Control | 0.8 | 1.5 a | 0.8 | 1.0 |
| | Actara™ | 0.5 | **0.5 bc** | 0.8 | 0.3 |
| | Confidor Guard™ | 1.0 | 1.0 ab | 0.8 | 0.3 |
| | SCSI-02 Soil | 2.3 | **0.5 bc** | 1.3 | 0 |
| | SCSI-03b | 1.3 | **0 c** | 0.3 | 0.3 |
| | Dimethoate™ | 1.5 | **0 c** | 0.5 | 0 |
| | SCSI-01 | 0.8 | **0 c** | 0.5 | 0.3 |
| | SCSI-02 Foliar | 0.8 | **0.3 bc** | 0.5 | 0.3 |

***Harvest***

A final assessment of cob damage and numbers of caterpillars, aphids and thrips was performed at harvest (83 DAS; 30th April 2007) (Table 65).

No caterpillars were found in the SCSI-02 foliar treatment at harvest, compared to a total of 4 caterpillars (helicoverpa, sorghum head caterpillar and yellow peach moth) in the control ($P < 0.05$). There was also no recorded cob damage in this treatment, compared to 1.3 damaged cobs in the control, although cob damage data were insufficient to determine whether this difference was statistically significant.

There were no aphids present at harvest in the Confidor Guard™, Actara™, SCSI-03b and SCSI-01 treatments, compared to an average of 8.8 in the control. However, aphid distribution was extremely patchy. For example, the high number of aphids in the dimethoate treatment was due to only two plants in a single plot, with the vast majority on one plant; aphids in the control were found on only three plants in three plots. Data were therefore not subjected to statistical analysis.

A high population of thrips was present at harvest: an average of 97 thrips per cob in the control treatment. There were significantly fewer thrips in the dimethoate treatment compared to the control (an average of 22 thrips per cob), but none of the other treatments were found to have a significant effect on the thrips population.

Table 65. Mean cob damage (number damaged cobs/10 plants) and mean densities of caterpillars, aphids (number/10 cobs) and thrips (number/cob). Treatment means in the same column sharing a common letter are not significantly different (LSD test at *P* = 0.05). Numbers significantly lower than the control are highlighted in bold.

| Treatment | Cob damage | helicoverpa | SHC | YPM | Total Leps | Aphids | Thrips |
|---|---|---|---|---|---|---|---|
| Unsprayed control | 1.3 | 1.0 | 2.5 | 0.5 | 4.0 ab | 8.8 | 97.2 ab |
| Actara™ | 1.0 | 0.8 | 3.8 | 0 | 4.5 ab | 0 | 70.1 b |
| Confidor Guard™ | 2.0 | 1.3 | 3.5 | 0.3 | 5.0 ab | 0 | 73.3 ab |
| SCSI-02 Soil | 0.8 | 0.5 | 4.0 | 0.5 | 5.0 ab | 12.3 | 98.8 a |
| SCSI-03b | 1.8 | 1.0 | 3.0 | 0.8 | 4.8 ab | 0 | 92.5 ab |
| Dimethoate™ * | 2.7 | 3.3 | 3.3 | 0.7 | 7.3 a | 69.3 | **22.2 c** |
| SCSI-01 | 1.0 | 1.0 | 1.5 | 0 | 2.5 bc | 0 | 86.7 ab |
| SCSI-02 Foliar | 0 | 0 | 0 | 0 | **0 c** | 1.0 | 71.9 ab |

* 3 replicates only

## 5.20 Monitoring Pests and Beneficial Organisms - Results.

The results of the work program have demonstrated that four (4) 'soft options' insecticides and one (1) miticide have potential, for the management of insect and mite pests in the Australian sweet corn industry. **These "soft options" pesticides appear to have low impacts on beneficial insects and spiders.**

Movento™ and SCSI-03, are effective against sucking insects (thrips and aphids); Belt™ and Coragen™, are very effective against Helicoverpa and Sorghum Head Caterpillar, and Paramite™, suppresses 2-spotted spider mite populations.

Although the work program has demonstrated that these soft options have a low to moderate impact on a small range of beneficials, additional investigations are required to provide a much better understanding of the impacts of these additional sucking pests and lepidopteran "soft options" (Movento™, SCSI-03, Belt™ and Coragen™) on beneficial arthropods.

Additionally, there will be value in better understanding the contribution to pest management of a wider range of naturally occurring beneficial arthropods including brown and green lacewings, ladybirds, spiders and damsel bugs, which occur regularly in sweet corn fields. Project results indicate that their contribution to the biological control of Helicoverpa and sucking pests is important, but quite variable from season to season and field to field.

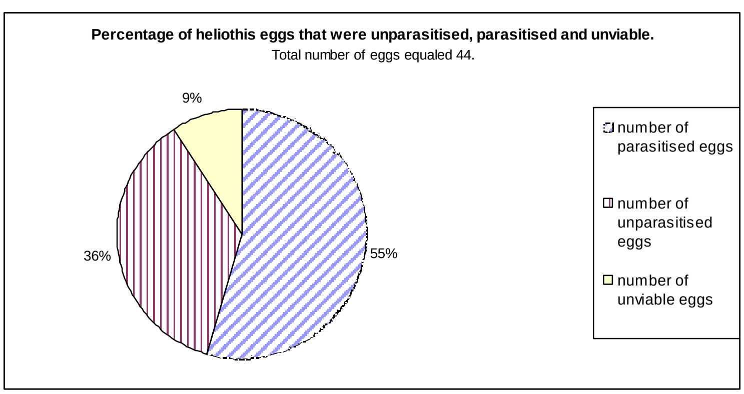
### 5.21 New South Wales - Monitoring Pests and Beneficials - Results

#### a) Additional 2007 non-replicated Trial - Results

In February and March of 2007 the efficacy of two new Lepidoptera insecticides (SCLI-O1 and SCLI-02), were compared in their ability to control helicoverpa in sweet corn with alpha cypermethrin and a control treatment of no spray. Efficacy against helicoverpa and some common beneficial insect species was investigated in a **non-replicated** trial at Yanco Agricultural Institute NSW.

Helicoverpa eggs were collected in the field between tasselling and harvest to determine the level of parasitism for each treatment. Eggs were collected and stored in the laboratory until the eggs hatched. The number of eggs collected varied according to abundance in the plots. Numbers of parasitized and unparasitised eggs were determined for each treatment. All emerged wasps were later identified as *Trichogramma sp*.

Graph 17: The proportion of eggs collected and observed for parasitism during the pre-treatment monitoring stage from the 23rd January, 31st January and the 6th of February.




Note: Unparasitised eggs are eggs from which helicoverpa larvae emerged

Table 66:
Numbers of parasitised, non parasitised and unviable eggs collected and observed in egg trays from the pre-treatment period through to week two.

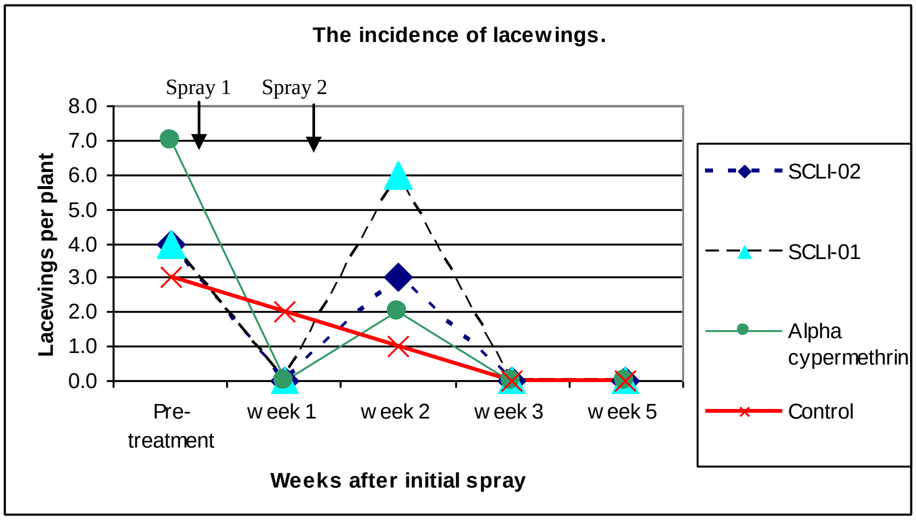
| Week | Plot | Date. | Total egg number. | Number of parasitised eggs. | Number of unparasitised eggs. | Number of unviable eggs. |
|---|---|---|---|---|---|---|
| 1 | 1 | 12 Feb | 21 | 10 | | 11 |
| 1 | 2 | 12 Feb | 9 | 4 | | 5 |
| 2 | 3 | 19 Feb | 21 | 5 | | 16 |
| 2 | 4 | 19 Feb | 22 | | | 22 |
| 3 | 1 | 26 Feb | 18 | | | 18 |
| 3 | 2 | 26 Feb | 20 | | | 20 |
| 3 | 3 | 26 Feb | 21 | 1 | | 20 |
| 3 | 4 | 26 Feb | 23 | 1 | | 22 |

Table 66 shows that ten parasitised eggs were found Wk1 in the SCLI-02 treated plot and four parasitised eggs were found in the SCLI-01 plot. No unparasitised eggs were found in week one in any of the treatment plots. In Wk2 only five viable eggs were collected, these were parasitised eggs and were from the alpha cypermethrin treated plot.
In Wk3 two parasitised eggs were collected one from the control plot and one from the alpha cypermethrin plot. The results show that there were a large number of unviable eggs that were observed in the laboratory. This may have been due to the extreme heat present during egg collection and/or mechanical damage incurred whilst collecting and traying eggs. The low numbers of viable eggs make it difficult to form any firm conclusions from the results. *Trichogramma sp* can take up to ten days from egg to adult, therefore parasitised specimens found in Wk1 (12$^{th}$ Feb) may have been parasitised before the 1$^{st}$ spray treatment applied on the 7$^{th}$ February. Alpha cypermethrin is known to be toxic against egg parasitoids so it is a possibility that the parasitised eggs found in the alpha cypermethrin treated plot in Wk2 and Wk3 were parasitised by wasps that moved into that plot from nearby corn crops after the residues from each spray had been reduced sufficiently by the overhead irrigation to enable their rehabitation of the alpha cypermethrin treated plot.

## Beneficial Insects:

Below are the results showing populations of the major beneficial insects in each of the treatment plots from pre-treatments through to post harvest. Data was collected during field monitoring for Wks1-5 excluding Wk4. During field monitoring twenty plants per plot were inspected and insect numbers per plant are reported in the graphs below. Wk4 results were obtained from the harvest assessment where sixty cobs per plot were harvested and inspected in the lab for beneficial insects. These results below include adults and juvenile numbers for all of the insects listed.

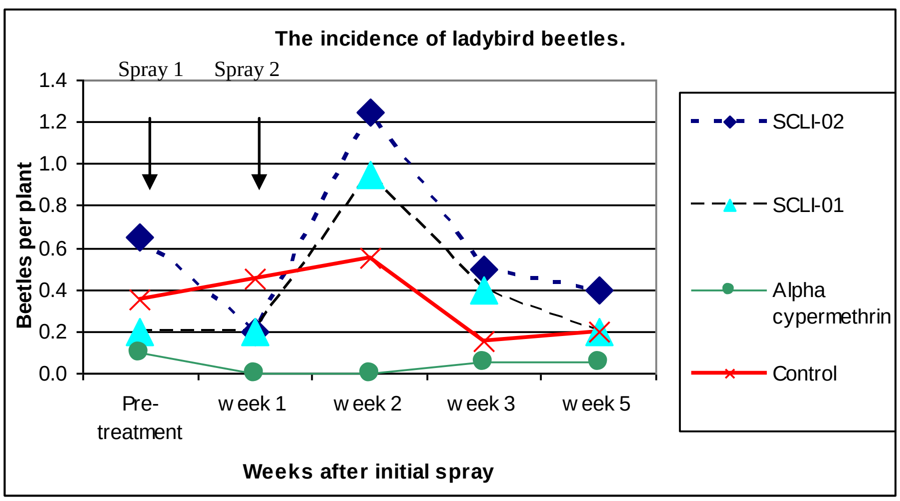
Graph 18: The number of lacewings per plant from pre-treatments through to post harvest.




Note: These figures include both brown and green lacewing numbers.

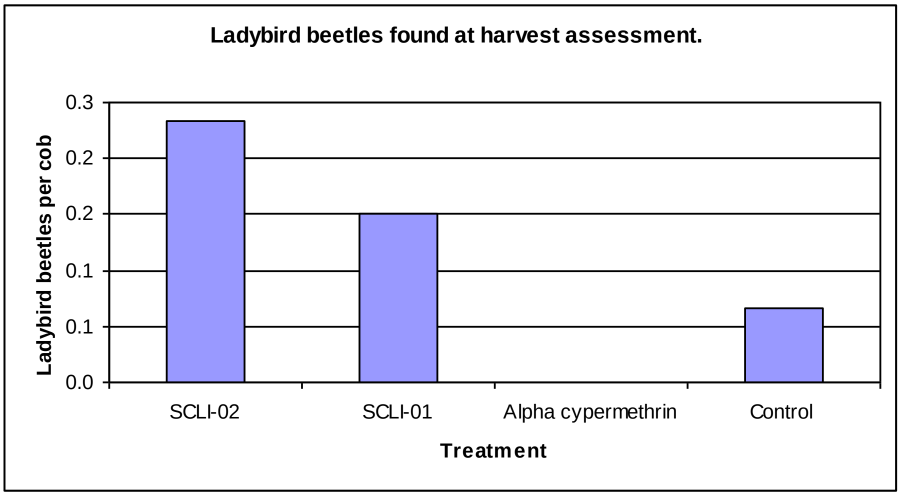
The results from the lacewing populations in this trial were inconclusive as to the effects of the three spray treatments due to low lacewing numbers present and large variability between the plots for the pre-treatment counts. Alpha cypermethrin is known to be harsh on lacewings but results do not clearly reveal that. There is no data for lacewings from the harvest assessment as none were present.

Graph 19: The number of ladybird beetles per plant from pre-treatments through to post harvest.




Note: These figures incorporate white collared, transverse, two spotted minute, striped ladybird beetles and ladybird larvae.

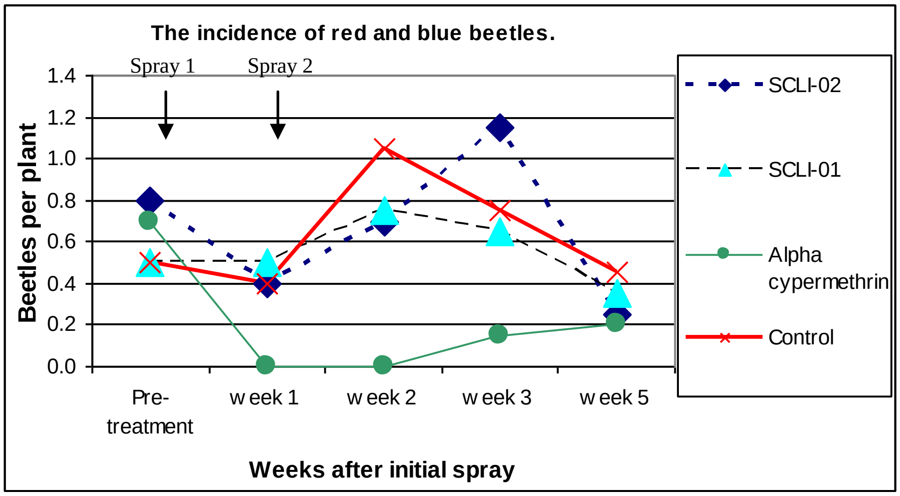
Graph 20: The number of ladybird beetles per cob for each of the treatments at harvest assessment; 1st March 2007.



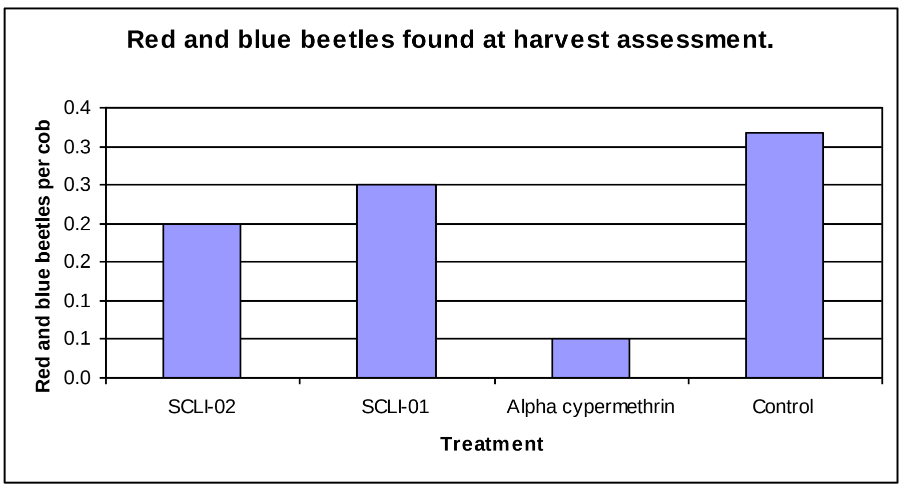

Note: These figures incorporate white collared, transverse, two spotted minute and striped ladybird beetles.

Pre-treatment results showed a large variability between the different plots. For the SCLI-02 and SCLI -01 treated plots, ladybird beetle numbers did not fall below 1 to every five plants or reach more than five to every six plants. Ladybird numbers within the control plot ranged from less than one to every 5 plants to more than one on every second plant. The peak populations were found in Wk2. The population within the alpha cypermethrin treated plot was one to every two plants pre-treatment and dropped to 0 for Wks 1 and 2 rising to one per twenty plants for Wks 3 and 5. The peak population of one ladybird beetle was found in both Wks 3 and 5. The SCLI-02 and SCLI-01 treated plots both had distinctly larger populations than the control for Wks 2 and 3. The population then dropped to less than one beetle for every two plants for all of the treatments in Wk5 as numbers dropped off and began to even out throughout the crop. Results from the harvest assessment supported those from the field monitoring showing no specimens found on cobs from the alpha cypermethrin treated plot and substantially larger numbers found on the cobs from the SCLI-02 and SCLI-01 treated plots as compared to cobs from the control plot. These results have indicated that both SCLI-02 and SCLI-01 are non toxic to ladybird beetles. Alpha cypermethrin is known to be toxic to ladybird beetles and the trial results supported this.

Graph 21: Number of red and blue beetles per plant from pre-treatments through to post harvest.

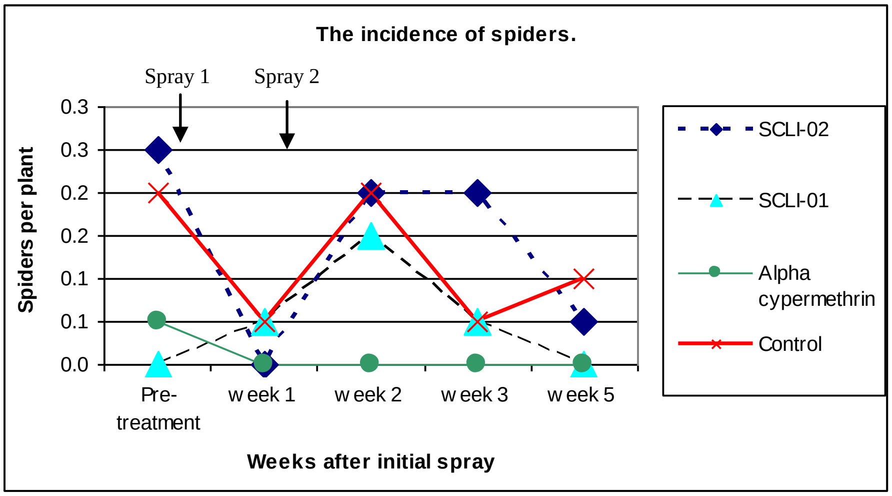



Graph 22: The number of red and blue beetles per cob for each of the treatments at the harvest assessment.

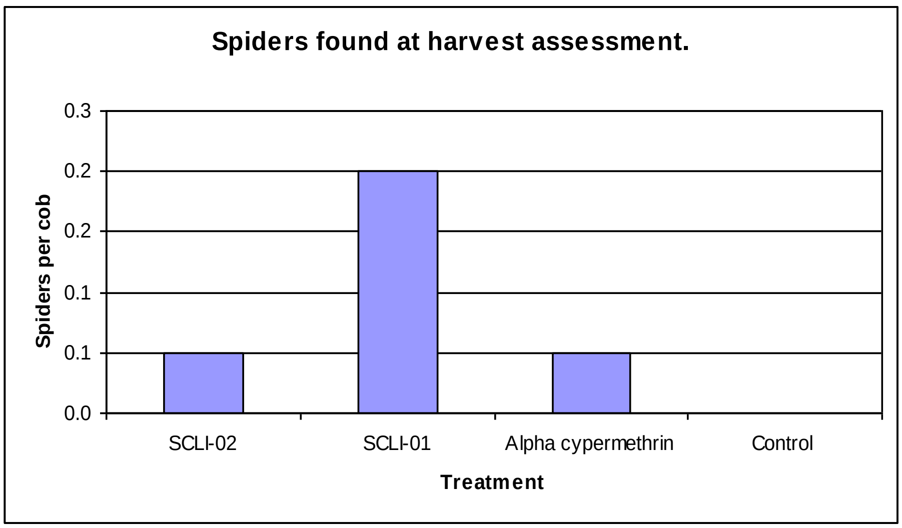



Pre-treatment counts showed a difference of 6 red and blue beetles per twenty plants between the SCLI-02 and SCLI-01 plots. Pre-treatment population variability as well as such low populations during the trial limits the ability to interpret the results. Both the SCLI-02 and SCLI-01 treated plots had very similar population trends with only slightly lower numbers of red and blue beetles to those seen in the control plot. This indicates that it is likely that SCLI-02 and SCLI-01 have no or very little toxic effect upon red and blue beetles. Population levels found in the Alpha cypermethrin treated plot were noticeably low, never exceeding one beetle on every five plants as compared to more than one per plant for the SCLI-02 treated plot in Wk3. In Wk5 all of the treatments excluding alpha cypermethrin showed a drop in population to less than one beetle on every two plants, the population in the alpha cypermethrin treated plot showed a tiny population increase from 3 beetles per twenty plants in Wk3 to 4 in Wk5. As with the monitoring results the harvest assessment data showed no great differences in the populations between the SCLI-02 and SCLI-01 treated plots as compared to the control. The consistently low population within the alpha cypermethrin treated plot shows that alpha cypermethrin is toxic to predatory beetles.

Graph 23: The number of spiders per plant from pre-treatments through to post harvest.



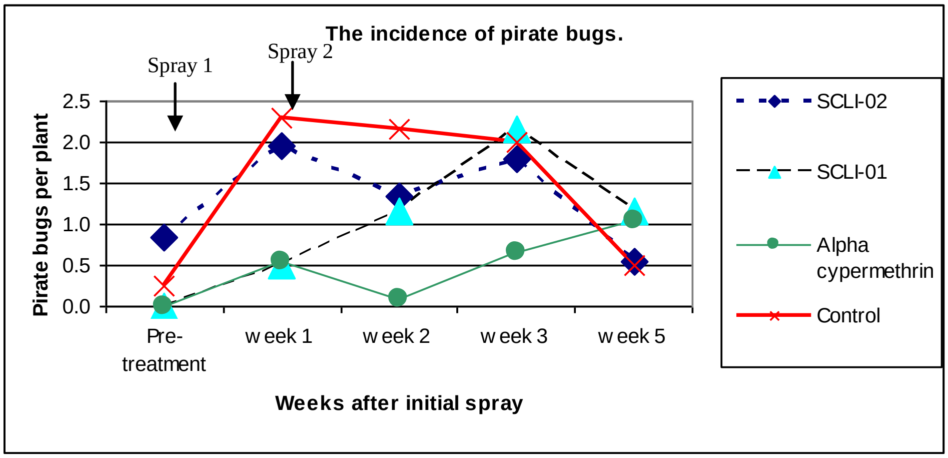

Graph 24: The incidence of spiders for each of the treatments at the harvest assessment; 1st March 2007.



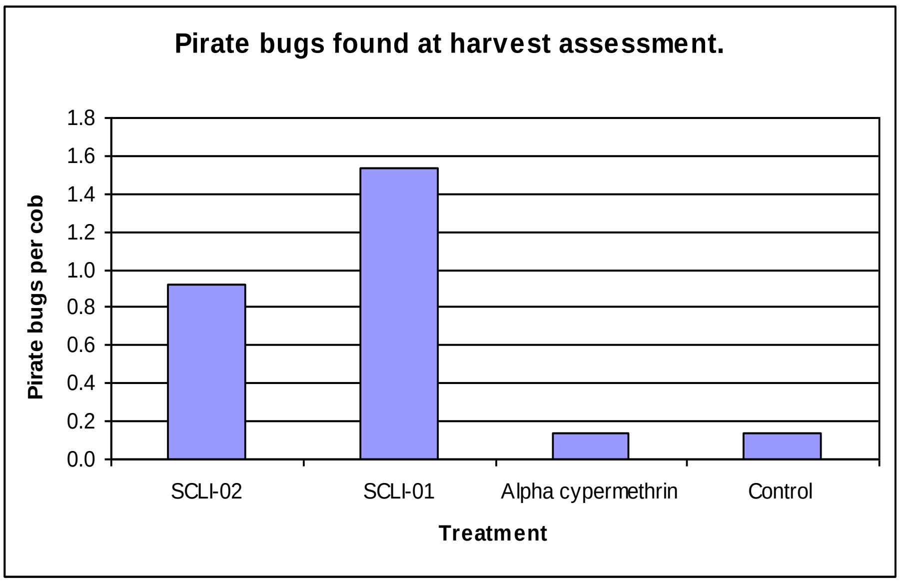

Pre-treatment results for spider counts also showed a high percentage of variability between the different treatment plots, this combined with very low spider numbers observed throughout the trial make it very difficult to draw conclusions from these results.

The results indicate that SCLI-02 and SCLI-01 are not toxic to spiders as spider populations within the SCLI-02 and SCLI-01 treated plots remained quite similar to those observed within the control for weeks one, two and three. Spider numbers did not exceed one on every five plants for any of the treatments in any one week. Alpha cypermethrin is known to be toxic to spiders and that information is supported in the data as no spiders were found in the alpha cypermethrin treated plot during monitoring following the initial spray.

Graph 25: The number of pirate bugs per plant from pre-treatments through to post harvest.

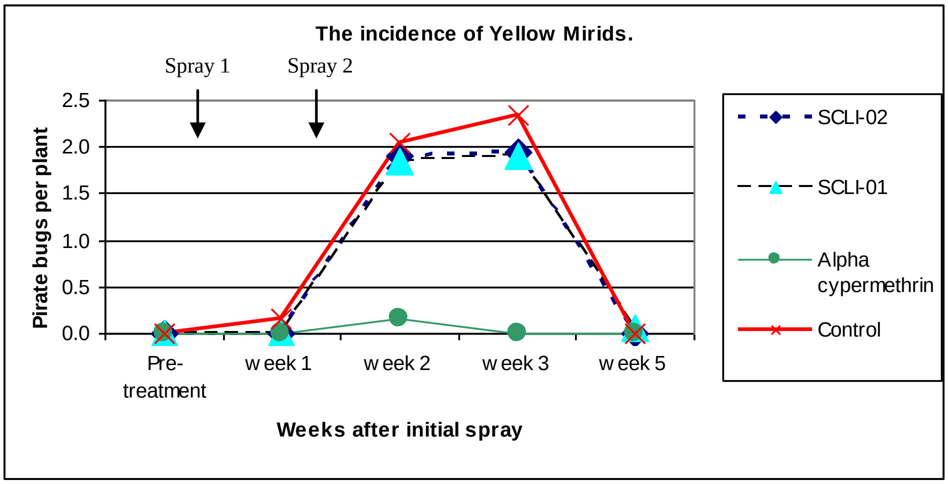



Graph 26: The number of pirate bugs per cob for each of the treatments at harvest assessment.

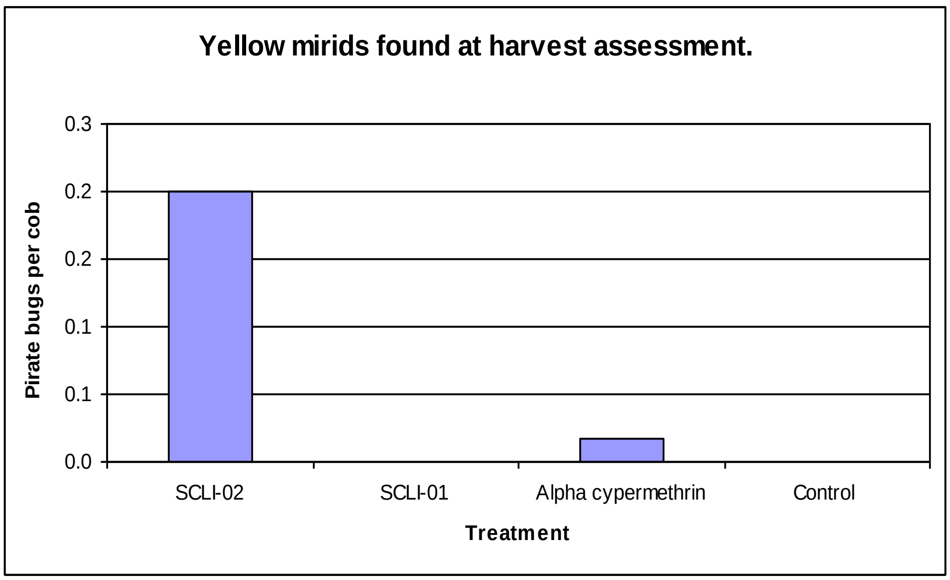



The pre-treatment results show a large range between the different plots which unfortunately makes it difficult to make interpretations of the data. In Wk1, forty six pirate bugs were found in the control plot on the twenty plants inspected, thirty nine in the SCLI-02 treated plot, ten in the SCLI-01 treated plot and eleven in the alpha cypermethrin plot. However in Wk2 pirate bug numbers in the SCLI-02 and SCLI-01 treated plot were twenty seven and twenty three (close to one per plant) respectively as compared to forty three (close to two per plant) in the control plot. Only two were found within the alpha cypermethrin plot (one per every ten plants). In Wk3 numbers found in the SCLI-02 and SCLI-01 treated plots were close to those found in the control plot, numbers in the alpha cypermethrin plot increased but were still much lower than in the other plots. In Wk5 results showed that the pirate bug population had shifted around indicating that migration between the plots was taking place. The harvest assessment showed that the SCLI-01 treated plot had the highest number of pirate bugs present on the cobs with ninety observed per sixty cobs which is less than two per cob as compared to the SCLI -02 treated plot with less than one per cob and the control and alpha cypermethrin treated plots with only eight for each plot equalling less than two for every ten cobs. The harvest data did support the monitoring data results as they reflected very low numbers across the different treatments. Data from weeks two and three indicates that SCLI-02 is slightly toxic to pirate bugs and that SCLI -01 is slightly more toxic to them. The data also indicates that alpha cypermethrin has moderate to high toxicity upon pirate bugs.

Graph 27: The number of yellow mirids per plant from pre-treatments through to post harvest.




Graph 28: The incidence of yellow mirids for each of the treatments at the harvest assessment.




The result for yellow mirids reveals that they were the only beneficials with little variability between plots for the pre-treatment counts. The field monitoring data indicates that both SCLI-02 and SCLI-01 have no toxicity upon yellow mirids as population trends in those treatment plots match quite closely with those seen within the control plot. Within the alpha cypermethrin treated plot, yellow mirid numbers did not exceed two per every ten plants as compared to the maximum of more than two per plant found in the control plot in Wk3. The harvest data reflects similar patterns to those seen from the monitoring data with low numbers found in all treatments.

## Sticky Traps:

Table 67: Sticky trap insect counts for week 1. - Placed 6 Feb collected 12 Feb

| Insects | SCLI 02 | SCLI 01 | Alpha cypermethrin | Control |
|---|---|---|---|---|
| Thrips | 55 | 69 | 22 | 90 |
| Predatory Thrips | 16 | 17 | 8 | 30 |
| Fly's /Mozzies | 11 | 13 | 29 | 25 |
| Wasps (small) | 19 | 8 | 5 | 9 |
| Wasps (large) | 1 | | | |
| Brown Leaf Hoppers | 1 | 5 | | 1 |
| Beetle Unidentified | 2 | | | |
| Aphids | 1 | 2 | 4 | 2 |
| Pirate bugs | 6 | 5 | 2 | 7 |
| Pumpkin beetle | | 1 | | |

Table 68: Sticky trap insect counts for week 2 - Placed 12 Feb and collected 19 Feb

| Insects | SCLI 02 | SCLI 01 | Alpha cypermethrin | Control |
|---|---|---|---|---|
| Thrips | 37 | 17 | 26 | 45 |
| Predatory Thrips | | | | 7 |
| Fly's /Mozzies | 13 | 15 | 18 | 13 |
| Wasps (small) | 6 | 2 | 7 | 11 |
| Wasps (large) | | | 1 | 1 |
| Green Leaf Hoppers | | 1 | | |
| Ladybird | 2 | 1 | 1 | 2 |
| Ladybird larvae | | 1 | | |
| Beetle Unidentified | 2 | 2 | | |
| Aphid | 4 | 9 | 4 | 2 |
| Hover fly | 5 | | 2 | |
| Moth | 1 | | | |
| Mites | | | 1 | |
| Pirate bugs | | 2 | | |

For all of the major beneficial insects that were caught on sticky traps, including ladybird beetles and pirate bugs, the data recorded is difficult to interpret because numbers caught in the treated plots often exceeded those found in the control plot. From the sticky trap data for thrips numbers, it is not possible to draw any conclusions as population numbers do not reveal trends and are rather random. This could be explained by the fact that thrips are winged and highly mobile within and between crops. It may be that thrips caught on these sticky traps were merely incidentals passing through the sweet corn trial from other food sources. Therefore results from the sticky trap observations were

Table 69: Specimens identified from sticky traps

| Common Name | Scientific Name | Order |
|---|---|---|
| Flea Beetle | Galerucinae | Coleoptera |
| White collared ladybird | *Hippodamia variegata* | Coleoptera |
| Lathrids | *Latheridae* | Coleoptera |
| Pumpkin Beetle | *Aulacophora spp* | Coleoptera |
| Fly | Sciaridae | Diptera |
| Fly | Chironomidae | Diptera |
| Fly | Brachycera | Diptera |
| Fly | Chloropidae | Diptera |
| Fly | Muscidae | Diptera |
| Hover Fly | Syrphidae | Diptera |
| Common brown leafhopper | *Orosius argentatus* | Hemiptera |
| Green leafhopper/ vegetable leafhopper | *Austroasca viridigrisea* | Hemiptera |
| Green Peach Aphid | *Myzus persicae* | Hemiptera |
| Maize Aphid | *Rhopalosiphum maidis* | Hemiptera |
| Maize Leafhopper (pale brown leaf hopper) | *Cicadulina bimaculata* | Hemiptera |
| Pirate Bug | *Orius spp* | Hemiptera |
| Wasp | Braconidae | Hymenoptera |
| Wasp | Chalcidae | Hymenoptera |
| Wasp | *Trichogramma spp* | Hymenoptera |
| Wasp | Bethylidae | Hymenoptera |
| Wasp | Scelionidae | Hymenoptera |
| Wasp | *Trichogrammanza* | Hymenoptera |
| Wasp | Gonatocerenae | Hymenoptera |
| Wasp | *Trichogramma pretiosum* | Hymenoptera |
| Onion Thrips | *Thrips tabaci* | Thysanoptera |
| Plague Thrips | *Thrips imaginis* | Thysanoptera |
| Thrips | *Australothrips bicolor* | Thysanoptera |
| Thrips | *Desmothrips tenuicornis* | Thysanoptera |
| Thrips | *Haplothrips robustus* | Thysanoptera |
| Thrips | *Haplothrips froggatti* | Thysanoptera |
| Thrips | *Podothrips spp* | Thysanoptera |
| Thrips | *Tenothrips frici* | Thysanoptera |
| Thrips | *Haplothrips sp* | Thysanoptera |
| Tomato Thrips | *Frankliniella shultzei* | Thysanoptera |
| Western flower thrips | *Frankliniella occidentalis* | Thysanoptera |

### b) 2007-08 Trials - Results

Two trials were conducted during the 2007/08 season at the Yanco Agricultural Institute, NSW, to assess the efficacy of different spray programmes that were based either on new generation, narrow spectrum chemicals or older broad spectrum chemicals for controlling helicoverpa (*Helicoverpa armigera*). Two spray programs (treatments) evaluated the use of SCLI-02 when first applied at silking.

Tables 70 and 71 list the final beneficial insect count. Numbers in the same column sharing a common letter are not significantly different by LSD test at P = 0.05.

Table 70. : Beneficial insect count per 20 plants found in Trial 1 on 29/1/08

| **Treatment** | | **Ladybird beetles** | **Other beetles** | **Lacewings** | **Predatory bugs** | **Spiders** |
|---|---|---|---|---|---|---|
| T1 | Starting at Tasselling | 0.00 a | 9.25 b | 1.75 a | 1.75 a | 0.50 a |
| T2 | Starting at silking | 0.00 a | 11.25 b | 0.25 a | 1.25 a | 0.50 a |
| T3 | Grower with High Water | 0.50 a | 1.50 a | 0.00 a | 0.00 a | 0.25 a |
| T4 | Grower with Low Water | 0.00 a | 4.25 a | 0.00 a | 1.25 a | 0.00 a |
| T5 | Control | 1.50 a | 17.75 c | 1.25 a | 4.25 a | 0.25 a |

Table 71. : Beneficial arthropod count per 20 plants found in Trial 2 on 29/1/08

| **Treatment** | | **Ladybird beetles** | **Other beetles** | **Lacewings** | **Predatory bugs** | **Spiders** |
|---|---|---|---|---|---|---|
| T1 | Starting at Tasselling | 0.25 a | 11.75 b | 0.75 a | 1.50 a | 0.00 a |
| T2 | Starting at silking | 0.00 a | 12.50 b | 0.25 a | 0.50 a | 0.50 a |
| T3 | Grower with High Water | 0.00 a | 2.75 a | 0.00 a | 0.25 a | 0.75 a |
| T4 | Grower with Low Water | 0.00 a | 4.25 a | 0.00 a | 1.75 a | 0.25 a |
| T5 | Control | 0.50 a | 29.00 c | 0.50 a | 2.00 a | 0.25 a |

Treatment T5 (control) had significantly higher numbers of “other beetles” than all the 4 spray treatments. Treatments T1 and T2 (using narrow spectrum chemicals) had significantly higher numbers of “other beetles” than treatments T3 and T4 (using broad spectrum chemicals). The insects recorded as “other beetles” included flower, pollen and rove beetles. No distinction was made between these three beetles at the time of scouting (numbers were recorded collectively and it was impossible to separate them later). It was generally observed that flower beetles were the most abundant beetle in the trials, with pollen beetles seen in low numbers and rove beetles rarely observed. Even though the flower beetle was observed and recorded with “other beetles”, it is not considered a beneficial insect in sweet corn.

There was no statistical difference in numbers of ladybird beetles, lacewings, predatory bugs or spiders between any of the treatments. A non-significant trend was observed for lacewings and predatory bugs with higher numbers observed in treatments T1, T2 and T5 than those observed in the treatments T3 and T4 that relied on broad spectrum sprays.

### 5.22 Western Australia - Monitoring Pests and Beneficials - Results

From 23 November 2005 to 31 January 2007, monitoring was conducted once per week by the Department of Agriculture and Food WA at Wanneroo, approximately 25 km north of Perth. Additional information was obtained from a commercial IPM company (Manchil IPM) monitoring the same Wanneroo property (2007/08) and another commercial farm at Baldivis (2006/07). At both sites, sweet corn was grown on sandy soils on the Swan Coastal plain and irrigated by overhead irrigation.

The main arthropod pests found in sweet corn at the Baldivis and Wanneroo sites, when they occur and how they are controlled by growers is presented in Table 39.

**Detailed monitoring.** In the 2005/06 season, 51% of the sweet corn sampled had one or more pests; 49% of plants sampled were free of insect pests. Helicoverpa was the most common pest (74% of sample; Fig. 3) and numbers triggered the action threshold on 11 of 19 sampling occasions. Helicoverpa numbers ranged from a mean of 0.15-0.7/plant (fig. 3). Rutherglen bug comprised 17% of the sample, followed by thrips (various species including western flower thrips, 13%), corn aphid (8%) and two-spotted mite (3%). Though corn aphids were not as abundant as other pests, they required control on two occasions; none of the other pests required control. All pests were found on sweet corn in all months and at all plant growth stages, except for aphids and two-spotted mite which were more abundant toward the end of the growing season (February-April).

In the 2006/07 season, 52% of the plants sampled had one or more pests; 48% of plants were pest free. Helicoverpa was the most common insect pest, comprising 41% of the sample. Helicoverpa numbers ranged from 0.03/plant up to 0.8/plant, and the action threshold was triggered on only two of seven sampling occasions. Thrips were the next most abundant insect (various species including western flower thrips, 19%), followed by Rutherglen bug (17%) and two-spotted mite (2%). No aphids were found in the 2006/07 season, though this was attributed to sampling finishing in January compared to April the previous season.

**IPM monitoring.** Helicoverpa was the main pest identified at both sites in November 2006-March 2007 at Baldivis and November 2007-April 2008 at Wanneroo (Figure 4). Helicoverpa were present during all growth stages of sweet corn as larvae can infest all parts of the plant, including the stalk, leaf midribs, and cob. The percentage of plants infested by helicoverpa caterpillars ranged from 0-35% at Wanneroo to 0-19% at Baldivis. Recommendations to treat plants with insecticides were made if larvae were found during the tasselling/silking/cob stages. Sorghum head caterpillar was identified as an additional pest in January and February 2006 at Baldivis, with up to 50% of plants infested with sorghum head caterpillar. In late December-March 2008, sweet corn at the Wanneroo site was also affected by sorghum head caterpillar (Fig. 5), with up to 43% of the crop infested. Insecticide applications to control sorghum head caterpillar included Success™ (spinosad), Sonic™ (cypermethrin) and Dominex™ (alpha-cypermethrin). Sorghum head caterpillar numbers declined one to two weeks after insecticide application, but then increased again in numbers before the crop was harvested (Fig. 30).

## Table 72: main insect pests found in sweet corn in WA

| Species | Occurrence | Plant part found | Action Threshold | Current Control options |
|---|---|---|---|---|
| **Major pest** | | | | |
| Helicoverpa, *Helicoverpa armigera* (Hübner) | November, December, January, February, March, April | All growth stages. All plant parts. | Preventative releases of trichogramma at seedling stage | Seedling: release Trichogramma (eggs), monitor % parasitism |
| | | | Consider spraying if larvae are found in silks | Tasselling stage onwards: Gemstar™ (NPV; small-medium larvae) through irrigation |
| **Secondary Pests (late season)** | | | | |
| Sorghum head caterpillar, *Spodoptera litura* (Fabricius) | December-March | Silk through to harvest.<br>Leaves, cobs | Consider spraying if >10% plants affected, or if numbers continue to increase | Success™ (spinosad), Sonic™ (cypermethrin) or Dominex (alpha-cypermethrin) |
| Corn aphid, *Rhopalosiphum maidis* (Fitch) | January-April; highest populations occur in February-March | Silk through to harvest.<br>Leaves, tassels, cobs | Consider spraying if >15% plants affected | Chess™ (pymetrozine), Pirimor™ (pirimicarb) |
| **Occasional pest** | | | | |
| two-spotted spider mite, *Tetranychus urticae* Koch | January-March | Mature plants<br>leaves | Consider spraying if mite numbers are high and continue to increase | Acramite™ (bifenazate)<br>Natural populations of *Phytoseiulus persimilis* also occur and offer some control |
| **Present, not normally considered to be pests** | | | | |
| Thrips, various species including western flower thrips (*Frankliniella occidentalis* (Pergande)) | November-March, with population peaks in November | Mature plants leaves, flowers, silks | Do not normally cause economic damage | No action normally required. |
| Rutherglen bug *Nysius vinitor* Bergroth | November-April | All growth stages<br>Leaves, silk | None | Migratory pest. Could cause damage if plants attacked in high numbers at seedling stage. Adults probably feeding on pollen. |

Aphids and two-spotted spider mite were identified as late season pests. Up to 95% of plants were infested with aphids at Baldivis in March 2007 (Fig. 4). At Wanneroo, up to 80% of plants were infested in March 2008 (data for this bay not shown in graph). On some plants, the number of individual aphids exceeded 300 aphids/flower. Aphids were controlled by applications of either Chess™ (pymetrozine) or Pirimor™ (pirimicarb), with 2-3 applications of Chess™ and 1-2 applications of Pirimor™ per crop. Control of two-spotted spider mite was required on one sampling occasion in late January 2008. A single application of Acramite™ (bifenazate) was applied to the crop; mite numbers were reduced one week after application.

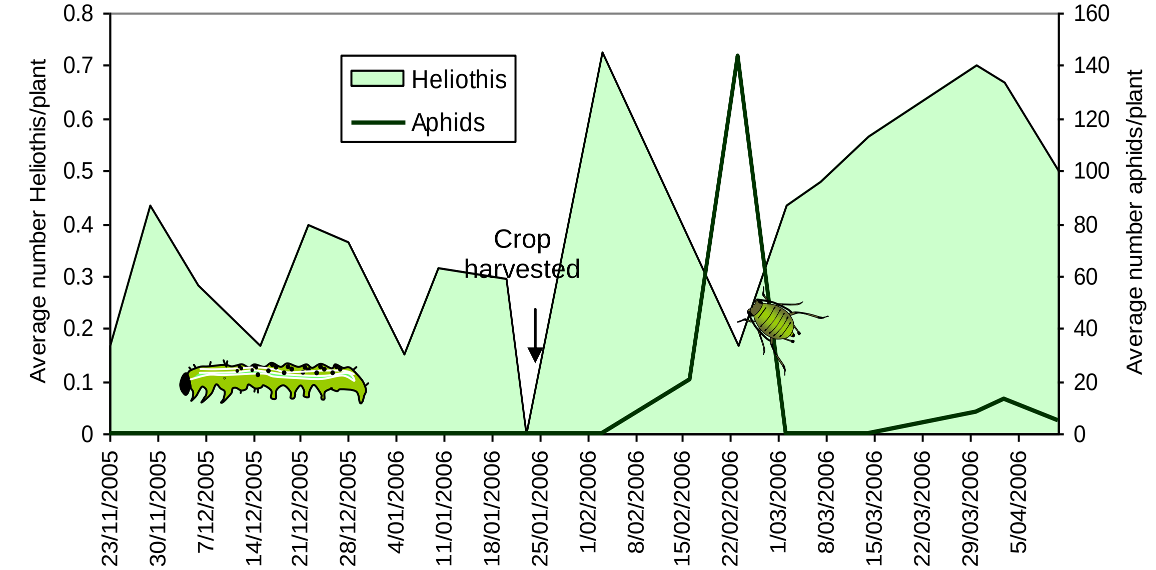



**Figure 28. Average number helicoverpa per plant and aphids per plant in the 2006/07 season at Wanneroo.**

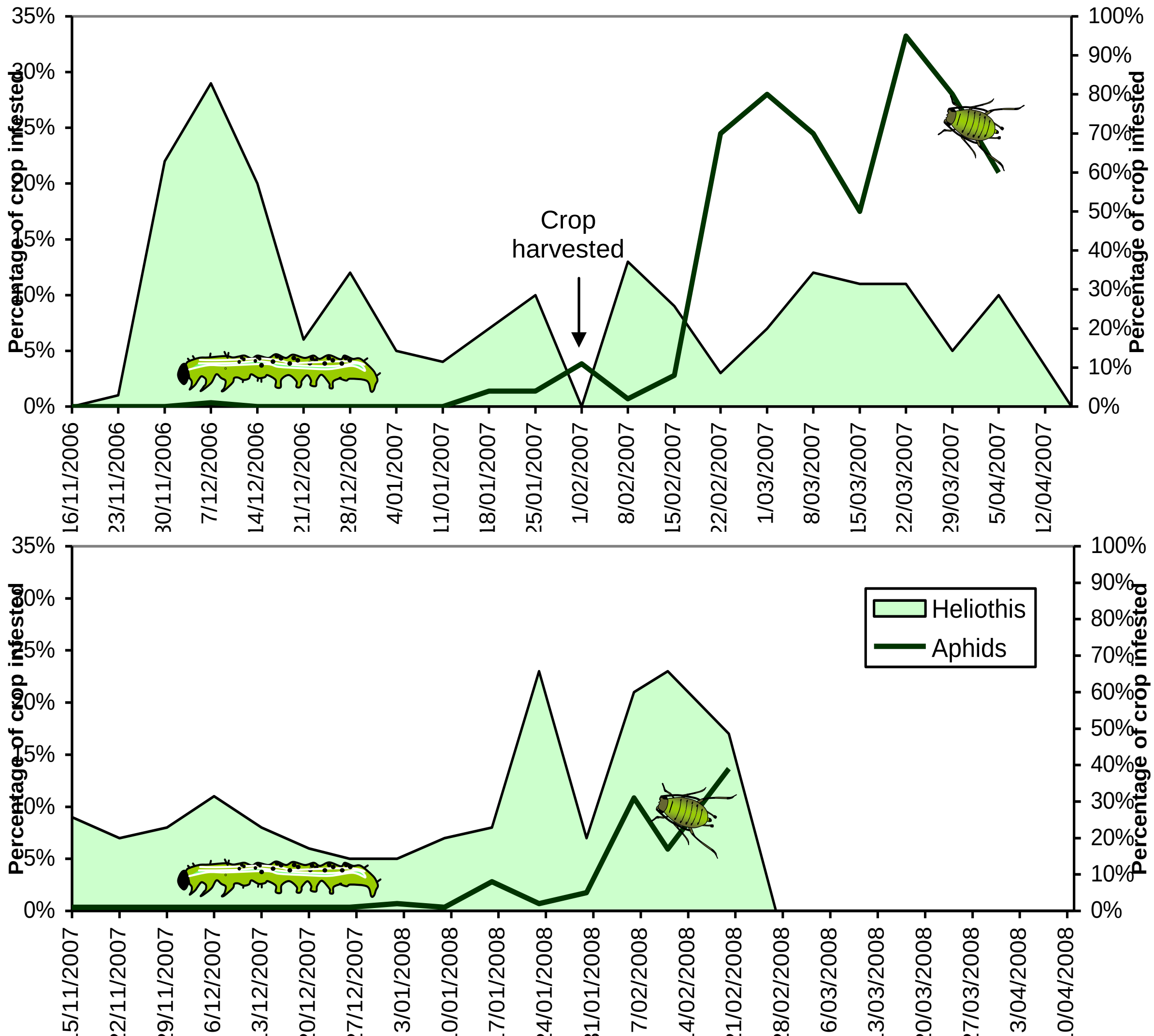



**Figure 29. Percentage of the sweet corn crop infested by helicoverpa and corn aphid over in the (a) 2006/07 season at Baldivis and (b) 2007/08 season at Wanneroo.**

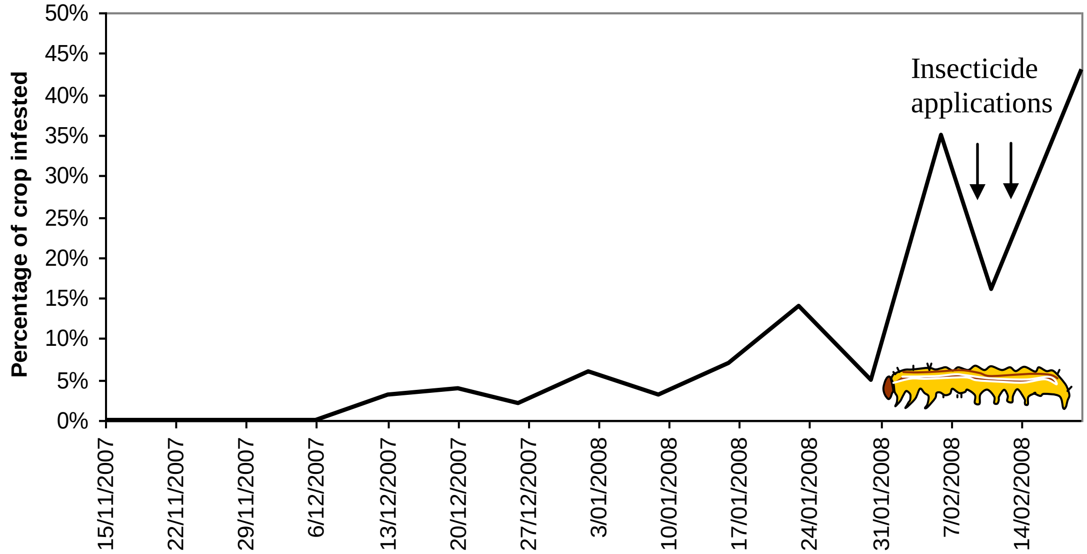



**Figure 30. Percentage of a sweet corn block infested with sorghum head caterpillar at Wanneroo (2007/08 season). Arrows indicate when insecticide applications of Sonic™ (cypermethrin) were applied.**

## Beneficials

### Naturally occurring beneficials

The main beneficials found in sweet corn during the study are shown in Table 73. The level of pest management of pests in sweet corn is based on Department of Primary Industries and Fisheries, Queensland (DPI & F, 2008) ratings. Naturally occurring predators included brown and green lacewings (*Micromus* spp.; *Mallada signata* (Schneider)), ladybirds (*Coccinella transversalis* Fabricius; *Hippodamia variegata* (Goeze)), spiders (various families), damsel bugs (*Nabis* spp.) and the Chilean predatory mite, *Phytoseiulus persimilis*, a mite predator of two spotted mite. In April 2008, a species of *Orius* sp. was documented for the first time from sweet corn at Wanneroo.

### Table 73: Naturally occurring beneficials found in sweet corn

| Common name, scientific name | Occurrence | Rating* |
|---|---|---|
| Neuroptera | | |
| Brown lacewing, *Micromus* spp. | Found throughout growing season, most abundant in November | ++ |
| Green lacewing, *Mallada signata* (Schneider) | November-December | ++ |
| Coleoptera | | |
| Transverse ladybird, *Coccinella transversalis* Fabricius | Found throughout growing season, most abundant toward end of season (February-March). *C. transversalis* more common than *H. variegata*. | +++ |
| spotted amber ladybird, *Hippodamia variegata* (Goeze) | | |
| Hemiptera | | |
| Damsel bugs (*Nabis* spp.) | Rare in our study; January-February | + |
| Spiders | Found throughout growing season | |
| Salticidae (jumping spiders) Lycosidae (wolf spiders) Araneidae (weavers). | Foliage dwelling | ++++ |
| | Soil dwelling | +++ |
| | | ++ |

* based on QDPI & F ratings. Level of pest management in sweet corn = Low (+); Moderate (+++); High (+++++).

### Detailed monitoring

Beneficials occurred on 17% of plants sampled in 2005/06 and 17% of plants sampled in the 2006/07 season. In 2005/06, adult lacewings comprising 90% of the sample were the most common predator, followed by adult ladybirds (19%), spiders (6%) and damsel bugs (2%).

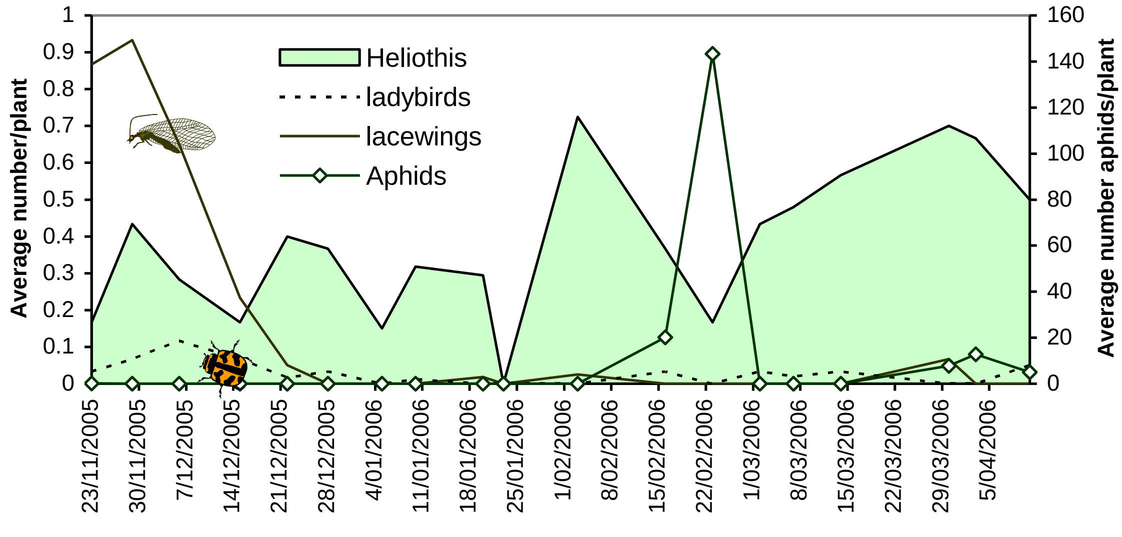



**Figure 31. Average number of lacewings and ladybirds at the Wanneroo site in the 2005/06 season.**

The average number of lacewings varied from 0.5 - 0.93 adults/plant, and ladybirds varied from 0.01-0.11/plant (Fig. 6). *C. transversalis* were more abundant than *H. variegata*, with a ratio of 1.8 *C. transversalis*:1 *H. variegata*. There appeared to be no correlation between lacewing and ladybird abundance with pest abundance (e.g. aphids, helicoverpa, Figs. 31 & 32). Damsel bugs were never abundant during our study and occurred only in January-February; with an average of 0.02 individuals/plant. Spiders were found during all months and ranged from 0.03 to 0.06/plant. Spiders were not identified to species, except for the distinctive Christmas spider (*Austracantha minax* (Thorell); family Araneidae). Other spider families collected during the study included other species of Araneidae (weavers), Salticidae (jumping spiders) and Lycosidae (wolf spiders).

In the 2006/07 season, spiders (38%) and ladybirds (38%) were the most common predators, followed by lacewings (10%) and damsel bugs (14%). Numbers of beneficials were lower, ranging from 0.05 ladybirds/plant in November 2006 to 0.02 ladybirds/plant in January 2007. Spiders ranged from 0.03 spiders/plant in November 2006 to 0.06 spiders/plant in January 2007.

### IPM monitoring

Beneficials were present in the crop throughout the growing season (Fig. 32). Based on estimates of the percentage of the crop hosting beneficials, ladybirds were more prevalent and abundant than brown and green lacewings (Fig. 7). Ladybird beetles (adults) were present on 4-21% of the crop at Wanneroo and 4-25% of the crop at Baldivis. Species included transverse and common spotted ladybirds. In March 2006, ladybird numbers increased to 95% in one bay at Baldivis, when aphid numbers were high (95% of crop infested).

Green lacewings were the least abundant group, found at the Baldivis site only in November-December 2006 (Fig. 32). The percentage of the crop with green lacewings varied from 2-5% at this time, compared to 4-14% for brown lacewings (Fig. 32). At Wanneroo, brown lacewings were present at all times. In November 2007, brown lacewing abundance reached a high of 40% in a single block (data not shown). This did not appear to be correlated with pest abundance, which was low for both helicoverpa (2% of crop infested) and aphids (1% of crop infested). We similarly had recorded high numbers of brown lacewings in our samples in the previous year (November 2006). Brown lacewings may be migrating from surrounding pastoral areas as weeds and broad acre crops dry up, and are probably attracted to corn for shelter and the pollen for food.

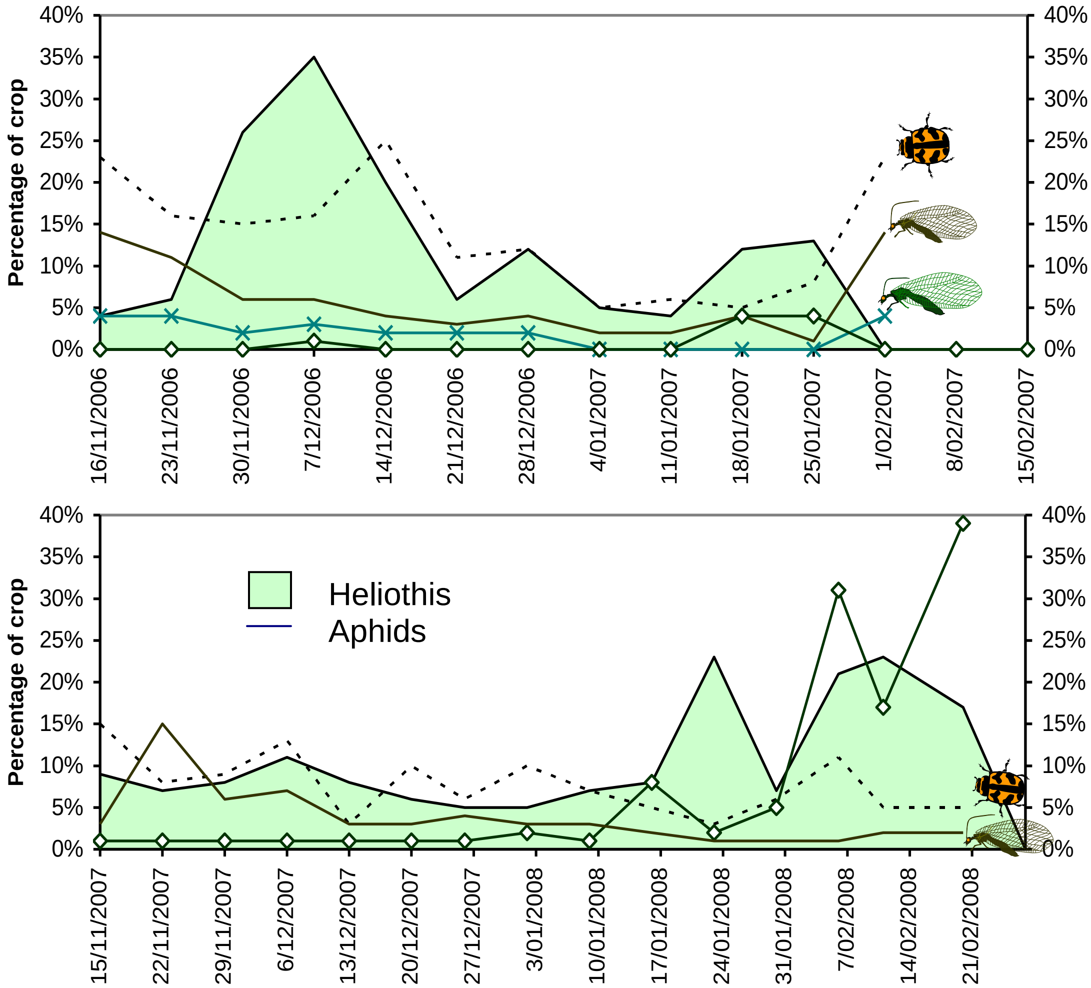



**Figure 32. Percentage of a sweet corn crop at Baldivis (2006/07 season) and Wanneroo (2007/08 season) hosting beneficials (green and brown lacewings, ladybirds) compared to common pests (helicoverpa and aphids).**

### Effect of insecticides on beneficials

The percentage of plants in a single sweet corn block with brown lacewings and ladybirds is shown in Figure 33. Insecticide applications included IPM friendly (Gemstar™) and broad-spectrum insecticides (Sonic™, cypermethrin) to kill helicoverpa and sorghum head caterpillar respectively.

Insecticide applications appeared to reduce, but not kill 100% of the beneficial population (Fig. 6).

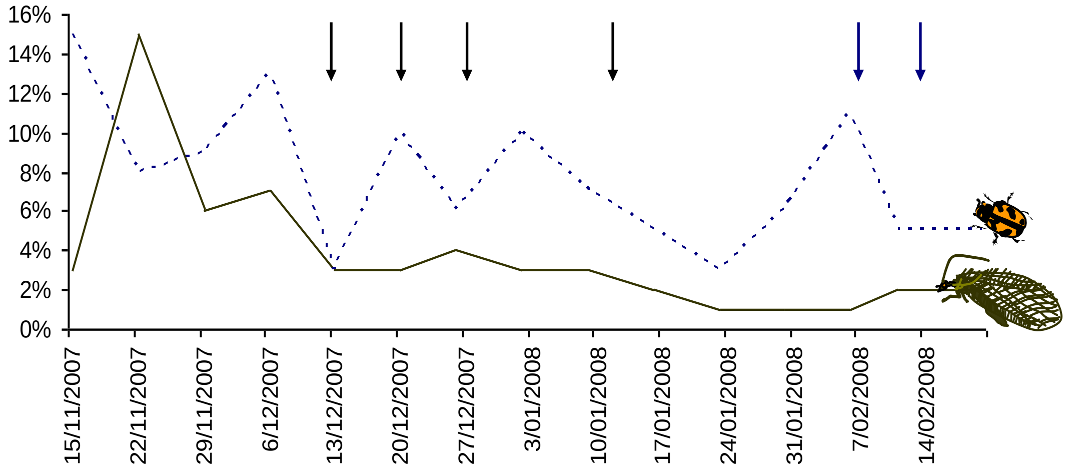



**Figure 33. Percentage of brown lacewings and ladybirds in a block of sweet corn at Wanneroo. Arrows indicate when insecticide applications of Gemstar™ (black arrows), Pirimor™ and Sonic™ (blue arrows) were applied to control pest insects.**

## Introduced biological control agents

**Trichogramma.** Trichogramma was obtained from BioResources P/L (Queensland). Releases were made at the vegetative stage and generally consisted of 1-3 releases, 7 days apart at the rate of 30,000 - 60 000 per hectare. Percent parasitism of helicoverpa eggs in individual blocks ranged from 0-6% at Wanneroo. This is similar to the natural egg parasitism (5%) rate of European corn borer, *Ostrinia nubilalis*, recorded throughout the United States in sweet corn (Musser et al. 2006). However, higher rates of parasitism occurred in individual sweet corn blocks, with up to 100% parasitism recorded in some blocks at Baldivis. Parasitism rates also appeared to increase over time in some blocks, which may be attributed to populations of trichogramma establishing in sweet corn during the growing season (Fig. 34).

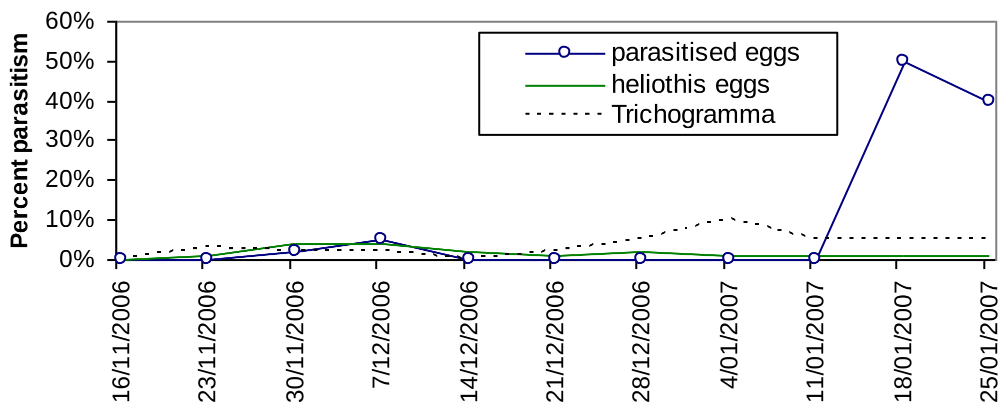
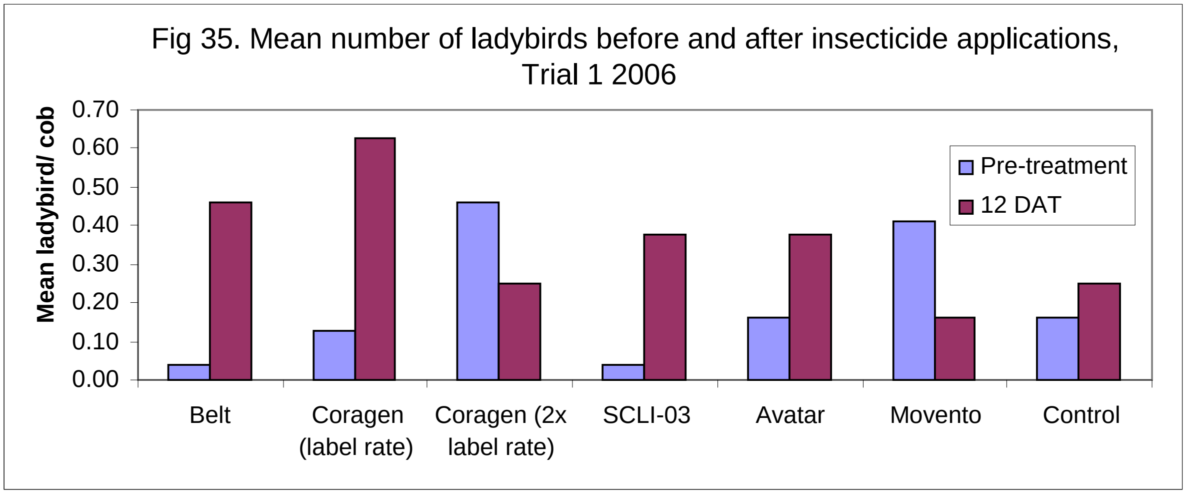



**Figure 34. Percent of eggs parasitised by** trichogramma **and percentage of crop with Trichogramma wasps compared to unparasitised helicoverpa eggs in a sweet corn block at Baldivis.**

## 5.23 North Queensland - Monitoring Pests and Beneficials - Results

### a) & b) Trials 1 and 2 (2006) - Results

**Beneficial arthropods**: The beneficial arthropods found in sweet corn during trials were ladybird beetles, lacewings, hoverfly brown smudge bugs and spiders. Ladybirds (larvae and adults) were most abundant in the crops (Fig 35). Three species, *Coccinella transversalis, Coelophora inaequalis and Stethorus sp*, were recoded. Ladybird numbers were similar in all treatments plots, and no significant differences were recoded between treated and untreated plots. SCLI-02 and SCLI-01 application did not cause any noticeable adverse effect on ladybird numbers in the plots (Fig 35).



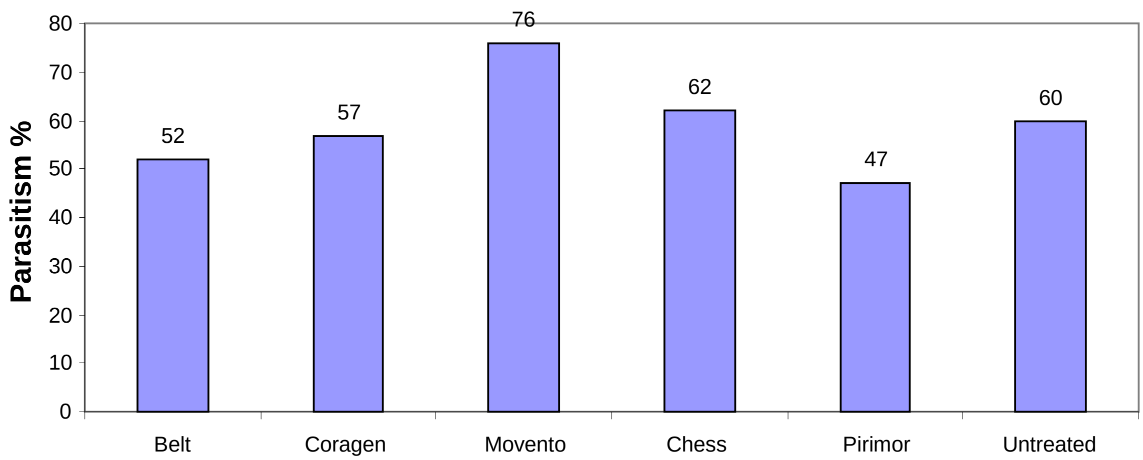

**Aphid parasitism**

Aphid parasitism was recoded in all treatments. A moderate level of parasitism was recorded in Pirimor™ plots. The parasitism levels ranged between 47 and 76 %. High levels of parasitism were recorded in the SCSI-01 plots, indicating that the product is relatively harmless to the parasitoid species (Fig 36). *Aphelinus sp*. was the most abundant species found in the trial crops. The adult wasp is black and yellow and 1.2 mm long (Photo 1). Parasitised aphids turn black when the parasitoid pupates within the aphid body and the mummified bodies remain attached to the leaf (Photo 2). A small proportion of another parasitoid, *Lysephlebus testaceipes* was also recorded.

Photo 1. *Aphelinus* parasitoid adult

Photo 2. Mummified aphids on a corn leaf

**Fig 36. Levels of aphid parasitism recorded in different treatments, Trial 3 2007**




**Beneficial insects**: The mite-eating ladybird beetle (*Stethorus sp*) was the major predatory insect species recorded on leaf and cob samples. *Stethorus* beetle and larval numbers did not vary significantly between treated and untreated plots, except for the lower numbers in the Avatar™ treatment. SCLI-02 and SCLI-01 treatments did not cause any noticeable adverse effects on ladybird numbers in the plots (Fig 37). *Stethorus* is a small (5 mm) black beetle and lays eggs in mite colonies. The larvae, which are grey in colour (Photo 3), together with the adults feed voraciously on mites eggs.

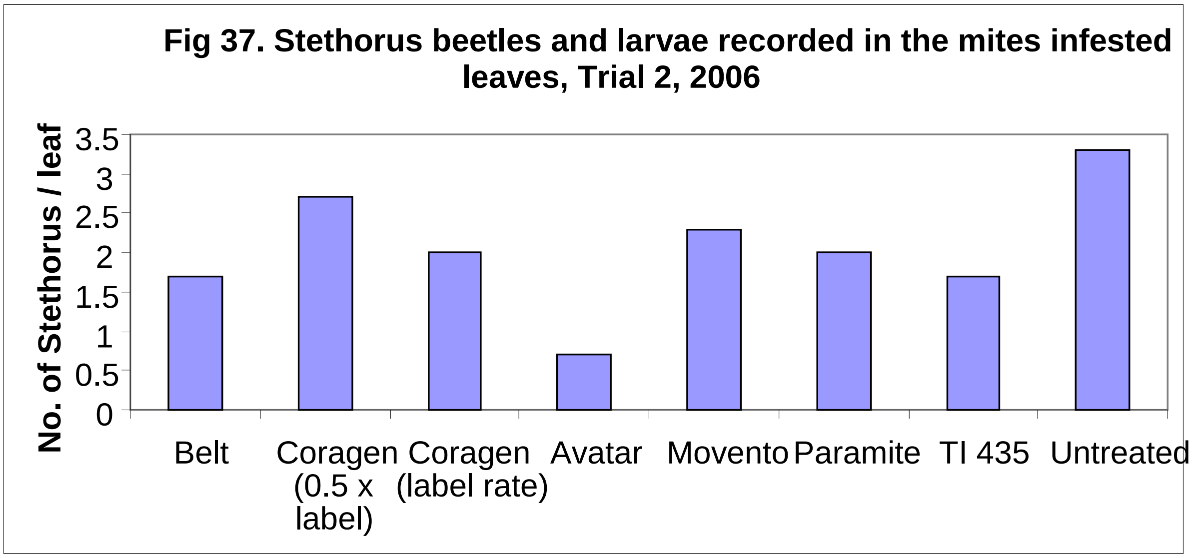



Photo 3. Mite-eating ladybird (*Stethorus*) larvae feeds on mites

## 5.24 South Queensland - Monitoring Pests and Beneficials - Results

Three trials were planted on the Gatton Research Station - 25th January and harvested on the 18th April 2006 using Hi-brix (formally H5); 7th September and harvested on the 4th December 2006 using Golden Sweet; and 6th February 2007 using Hi-Brix; to evaluate a range of insecticides for lepidopteran insects and sap sucking insect control, and to monitor the effects of insecticides on naturally occurring beneficials.

### a) Trial 1 - Results

Beneficial insect numbers were not significantly different between treatments as shown in Table 74. The most prevalent were spiders, pirate bug and the trichogramma egg parasitoid.

Table 74. Beneficial insect numbers trapped using yellow sticky traps placed at cob height within each treatment.

| Date | Treatments | Spiders | Trichogramma | Pirate bug |
|---|---|---|---|---|
| 30/3/2007 | Avatar™ | 0.00 | 2.50 | 0.25 |
| | Control | 0.00 | 2.00 | 0.00 |
| | SCLI-01 100 | 0.00 | 3.00 | 0.00 |
| | SCLI-01 150 | 0.00 | 3.75 | 0.00 |
| | SCLI-02 100 | 0.25 | 3.25 | 0.50 |
| | SCLI-02 200 | 0.00 | 2.75 | 0.00 |
| | SCLI-03 | 0.00 | 4.25 | 0.00 |
| | SCSI-01 | 0.25 | 2.75 | 0.00 |
| 6/4/2007 | Avatar™ | 0 | 1 | 0.5 |
| | Control | 0 | 2.75 | 0.25 |
| | SCLI-01 100 | 0.25 | 3 | 0 |
| | SCLI-01 150 | 0.25 | 1.5 | 0.5 |
| | SCLI-02 100 | 0 | 1.75 | 0.25 |
| | SCLI-02 200 | 0.25 | 3.25 | 0.5 |
| | SCLI-03 | 0 | 1.5 | 0.5 |
| | SCSI-01 | 0 | 2.5 | 0.25 |
| 12/4/2007 | Avatar™ | 0.25 | 2.25 | 0 |
| | Control | 0.5 | 2.25 | 0.25 |
| | SCLI-01 100 | 0 | 2 | 0 |
| | SCLI-01 150 | 0 | 1 | 0.25 |
| | SCLI-02 100 | 0.25 | 1.5 | 0.25 |
| | SCLI-02 200 | 0.75 | 2.75 | 0.25 |
| | SCLI-03 | 0 | 3.5 | 0.5 |
| | SCSI-01 | 0 | 1.5 | 0 |

All the insecticidal treatments did not appear to have any detrimental affect on the beneficial insect populations with similar numbers of the more commonly found beneficial insects being present throughout all the treatments during the silking period especially the egg parasitoid trichogramma.

### b) Trial 2 - Results

*Beneficial insects*

The two methods for assessing beneficial insects in the field were inconclusive. Direct field monitoring for beneficial insects only found significant differences between treatments during peak silking on the 16th November 2006 and only for the predatory bugs. The following week this difference was not there, however there were differenced in the numbers of predatory beetles found on the plants as seen in table 75 below. Predatory bugs increased over time with all treatments whereas the predatory beetles increased overtime with the majority of the treatments. Avatar™ may have some effect on the beetle populations within sweet corn as shown in Figure 38 and Table 75.

The use of yellow sticky traps showed very little differences between treatments during the silking period with predatory bugs showing the most significant differences on the 24th November 2006 with the unsprayed control plots harbouring significantly more beneficial bugs than a number of the insecticide treated plots as shown in Figure 38 and table 75.

Table 75. Direct field monitoring results of beneficial insects during sweet corn silking - Golden Sweet variety, Spring 2006.

| Date | Treatment | Lace wing | Spiders | Predatory bugs | Predatory beetles |
|---|---|---|---|---|---|
| 8/11/2006 | **Avatar™** | 0.00 | 0.80 | 0.00 | 0.30 |
| | **SCLI-02 100** | 0.30 | 0.80 | 0.50 | 0.50 |
| | **SCLI-02 200** | 0.5 | 0.80 | 0.50 | 0.00 |
| | **SCLI-01 100** | 1.5 | 0.30 | 0.80 | 0.00 |
| | **SCLI-01 150** | 1.30 | 0.5 | 0.80 | 0.50 |
| | **SCLI-03** | 0.5 | 0.30 | 0.50 | 0.00 |
| | **Unsprayed control** | 1.30 | 1.00 | 0.50 | 0.80 |
| | | | | | |
| 16/11/2006 | **Avatar™** | 0.00 | 0.30 | 5.50 BC | 0 |
| | **SCLI-02 100** | 0.00 | 0.30 | 4.75 BC | 0.5 |
| | **SCLI-02 200** | 0.00 | 0.50 | 6.25 BC | 0.25 |
| | **SCLI-01 100** | 0.50 | 0.30 | 6.75 BC | 0 |
| | **SCLI-01 150** | 0.30 | 0.00 | 4.00 C | 0 |
| | **SCLI-03** | 0.30 | 1.00 | 7.75 B | 0.5 |
| | **Unsprayed control** | 0.00 | 0.50 | 11.50 A | 0.75 |
| | | | | | |
| 24/11/2006 | **Avatar™** | 0.00 | 1.00 | 8.5 | 0.25 C |
| | **SCLI-02 100** | 0.00 | 0.80 | 8 | 0.75 BC |
| | **SCLI-02 200** | 0.00 | 0.00 | 6.75 | 1.50 ABC |
| | **SCLI-01 100** | 0.00 | 1.30 | 8 | 2.75 AB |
| | **SCLI-01 150** | 0.00 | 1.80 | 8.75 | 3.50 A |
| | **SCLI-03** | 0.30 | 0.50 | 8.5 | 1.00 BC |
| | **Unsprayed control** | 0.30 | 1.80 | 8.75 | 2.00 ABC |

Columns with the same letters are not significantly different from one another.
Predatory bugs = pirate bug, smudge bug, damsel bug, big-eyed bug, broken-backed bug, predatory shield bug, apple dimple bug,
Predatory beetles = the various ladybird beetles, red and blue beetles, small brown Anthicid beetle

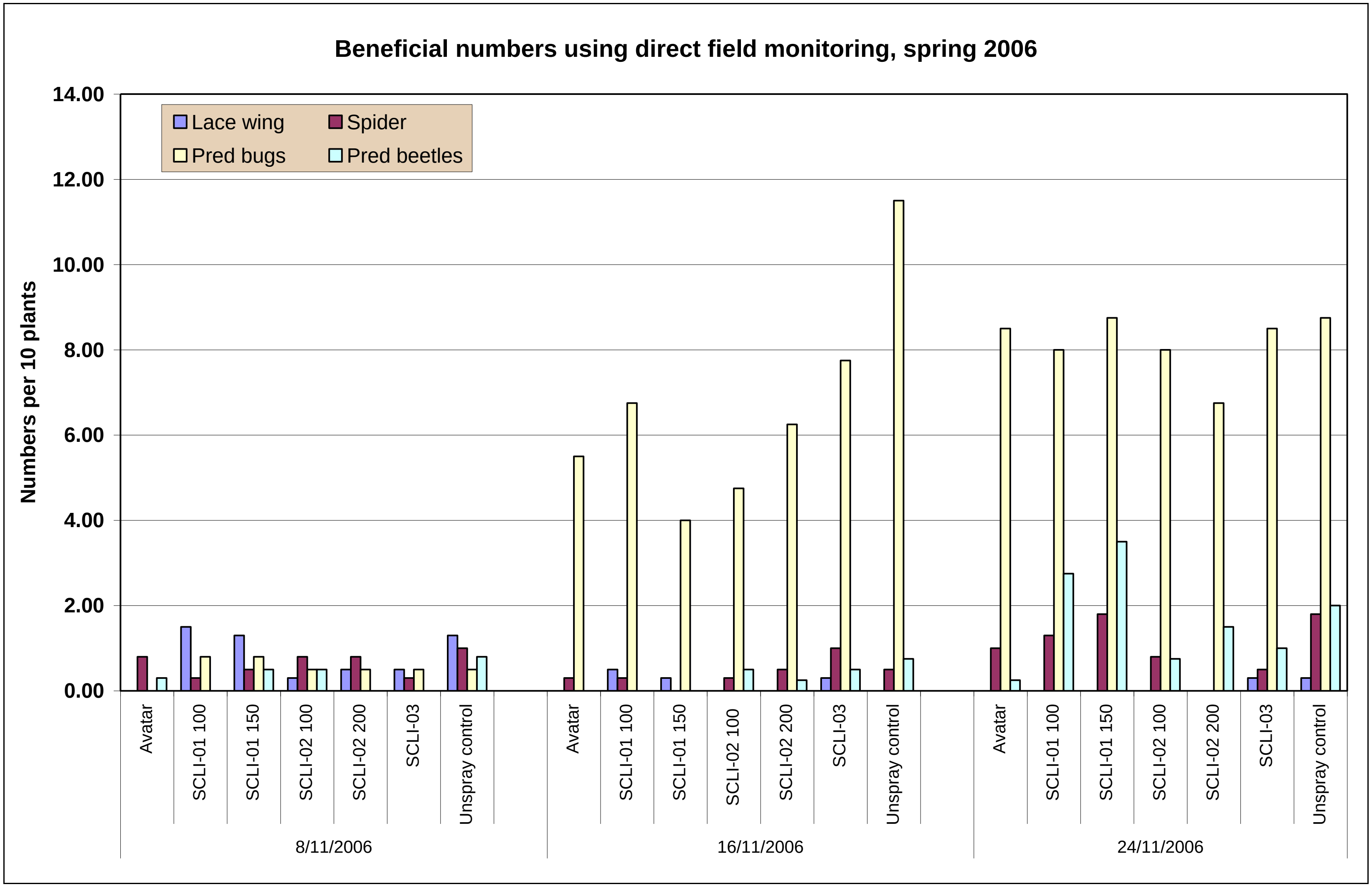



Figure 38. Numbers of beneficial insects found from early silking to 10 days before harvest or the brown silk stage. Monitoring carried out 3-4 days before the treatments were applied to the crop.

The use of yellow sticky traps showed very little differences between treatments during the silking period with predatory bugs showing the most significant differences on the 24th November 2006 with the unsprayed control plots harbouring significantly more beneficial bugs than a number of the insecticide treated plots as shown in Figure 39 and table 76.

Table 76. Yellow sticky trap counts after being left out for 24 hours for four weeks from early silking of sweet corn - Golden Sweet variety, Spring 2006.

| Date | Treatment | Trichogramma | Spiders | Lace wing | Predatory bugs | Predatory beetles |
|---|---|---|---|---|---|---|
| 8/11/2006 | Avatar™ | 4.00 | 0.50 | 0.5 | 1.75 | 0 |
| | Confidor™ | 3.00 | 0.00 | 0.50 | 1.25 | 0 |
| | SCLI-02 100 | 4.75 | 0.00 | 1.25 | 2.5 | 0 |
| | SCLI-02 200 | 4.25 | 0.25 | 0.25 | 2.75 | 0 |
| | SCLI-01 100 | 3.50 | 0.00 | 0.50 | 0.25 | 0 |
| | SCLI-01 150 | 5.50 | 0.00 | 0.75 | 1.75 | 0.5 |
| | SCLI-03 | 2.75 | 0.25 | 0.00 | 2.75 | 0 |
| | SCSI-03 | 4.75 | 0.00 | 0.00 | 0.5 | 0 |
| | Unsprayed control | 7.50 | 0.00 | 0.75 | 6.5 | 0 |
| | | | | | | |
| 15/11/2006 | Avatar™ | 2.25 | 0.00 | 0.25 B | 0.5 | 0 |
| | Confidor™ | 2.5 | 0.50 | 0.25 B | 0.5 | 0 |
| | SCLI-02 100 | 1.25 | 0.00 | 0 B | 0.75 | 0 |
| | SCLI-02 200 | 1.75 | 0.00 | 0.75 A | 0 | 0 |
| | SCLI-01 100 | 0.50 | 0.00 | 0 B | 0.25 | 0 |
| | SCLI-01 150 | 1.50 | 0.25 | 0.25 B | 0.75 | 0 |
| | SCLI-03 | 0.50 | 0.00 | 0 B | 0.5 | 0 |
| | SCSI-03 | 2.75 | 0.00 | 0 B | 0 | 0 |
| | Unsprayed control | 2.00 | 0.25 | 0 B | 0.75 | 0 |
| | | | | | | |
| 24/11/2006 | Avatar™ | 1.25 | 0.00 | 0.00 | 0 D | 0 |
| | Confidor™ | 1.50 | 0.00 | 0.00 | 1.75 ABCD | 0 |
| | SCLI-02 100 | 1.50 | 0.50 | 0.00 | 1 BCD | 0 |
| | SCLI-02 200 | 4.00 | 0.25 | 0.00 | 0.5 CD | 0 |
| | SCLI-01 100 | 1.50 | 0.25 | 0.00 | 2.5 AB | 0 |
| | SCLI-01 150 | 1.50 | 0.00 | 0.00 | 2.75 AB | 0.25 |
| | SCLI-03 | 1.25 | 0.25 | 0.25 | 2 ABC | 0 |
| | SCSI-03 | 2.00 | 0.00 | 0.00 | 1 BCD | 0 |
| | Unsprayed control | 2.00 | 0.00 | 0.50 | 3.5 A | 0 |
| | | | | | | |
| 30/11/2006 | Avatar™ | 0.00 | 0.00 | 0.25 | 0.5 | 0 |
| | Confidor™ | 0.50 | 0.25 | 0.25 | 0.75 | 0 |
| | SCLI-02 100 | 0.25 | 0.00 | 0.00 | 1.5 | 0 |
| | SCLI-02 200 | 0.00 | 0.25 | 0.25 | 1 | 0 |
| | SCLI-01 100 | 0.25 | 0.00 | 0.75 | 2 | 0 |
| | SCLI-01 150 | 0.00 | 0.25 | 0.25 | 1.75 | 0 |
| | SCLI-03 | 0.00 | 0.00 | 0.75 | 0.25 | 0 |
| | SCSI-03 | 0.25 | 0.00 | 0.00 | 0 | 0 |
| | Unsprayed control | 0.00 | 0.00 | 0.50 | 0.5 | 0 |

Columns with the same letters are not significantly different from one another.
Predatory bugs = pirate bug, smudge bug, damsel bug, big-eyed bug, broken-backed bug, predatory shield bug, apple dimple bug,
Predatory beetles = the various ladybird beetles, red and blue beetles, small brown Anthicid beetle

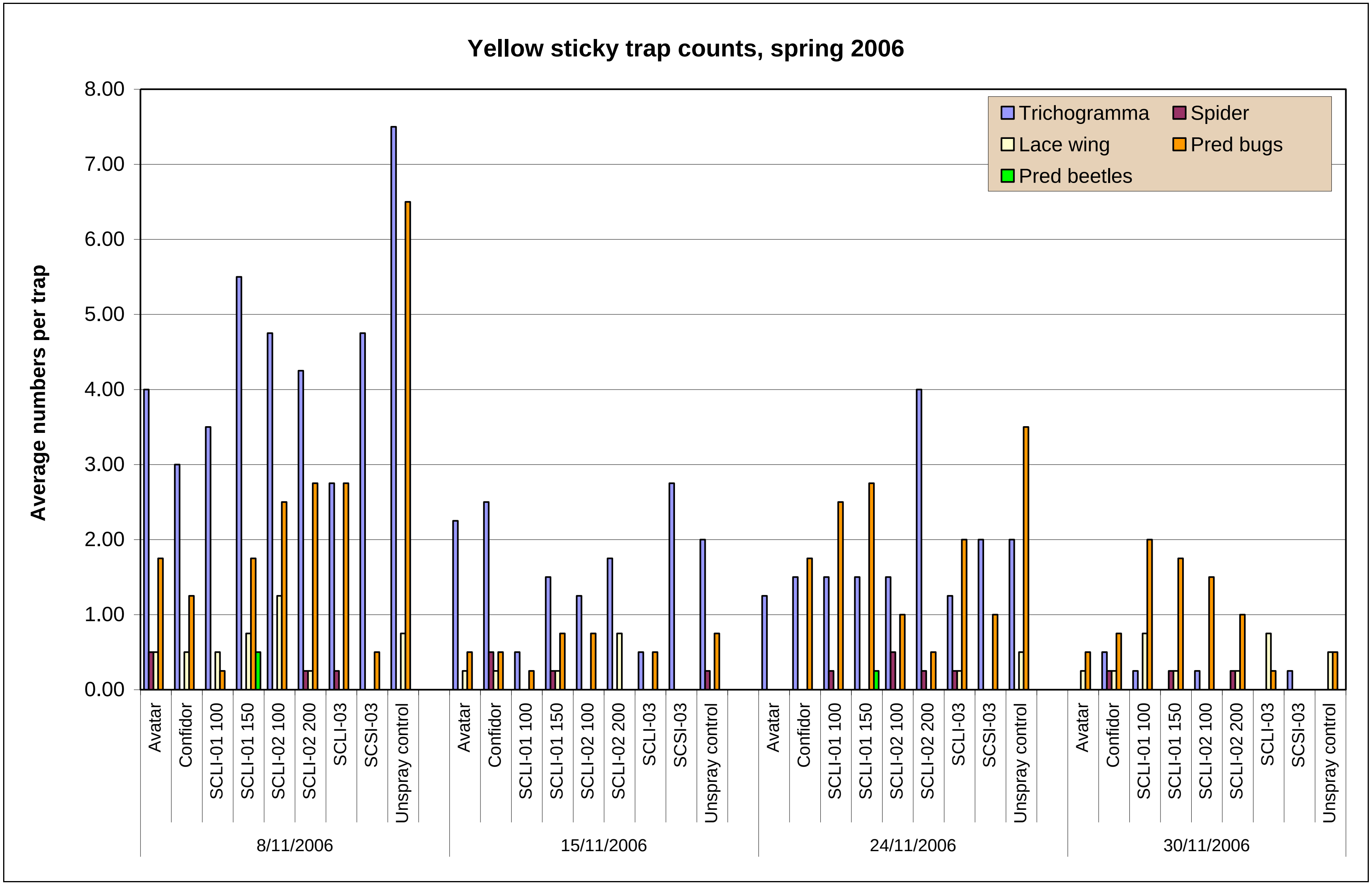



Figure 39. Numbers of beneficial insects found on yellow sticky traps placed in the crop at cob height and left there for 24 hours. Cards used during the silking period only.

### c) Trial 3 - Results

***Sowing to silking***

The main beneficial species recorded during the early stages of the crop were spiders and ladybirds (predominantly *Hippodamia variegata*, but also the transverse ladybird *Coccinella transversalis*) (Table 77). Low numbers of predatory bugs (brown smudge bugs *Deraeocoris signatus* and pirate bugs *Orius* spp.) were recorded at 27 DAS. In most instances numbers were too low to allow statistical analysis, however where data were analysed no significant effects of treatment were found.

Table 77. Mean densities (number/10 plants) of beneficial insects

| Beneficial | Treatment | 13 DAS (19/02/07) | 20 DAS (26/02/07) | 27 DAS (05/03/07) |
|---|---|---|---|---|
| Spiders | Unsprayed control | 1.3 | 0.5 | 2.0 |
| | Actara™ | 0.8 | 1.0 | 2.0 |
| | Confidor Guard™ | 1.3 | 0 | 1.3 |
| | SCSI-02 | 1.3 | 1.3 | 1.5 |
| | SCSI-03b | 0.8 | 1.0 | 1.3 |
| Ladybirds | Unsprayed control | 0 | 0 | 1.5 |
| | Actara™ | 0.3 | 0 | 1.3 |
| | Confidor Guard™ | 0.3 | 0 | 1.8 |
| | SCSI-02 | 0 | 0 | 0.8 |
| | SCSI-03b | 0 | 0 | 0.3 |
| Predatory bugs | Unsprayed control | N/A | N/A | 0.5 |
| | Actara™ | N/A | N/A | 0.3 |
| | Confidor Guard™ | N/A | N/A | 0 |
| | SCSI-02 | N/A | N/A | 0 |
| | SCSI-03b | N/A | N/A | 0 |

***Silking to harvest***

Parasitism of helicoverpa eggs fluctuated over the course of the trial, with no consistent or statistically significant differences amongst treatments (Table 78).

Table 78. Mean number of parasitised (black) helicoverpa eggs per 10 plants (expressed as a percentage of the total number of helicoverpa eggs in brackets).

| Treatment | 57 DAS (04/04/07) | 65 DAS (12/04/07) | 71 DAS (18/04/07) | 79 DAS (26/04/07) |
|---|---|---|---|---|
| Unsprayed control | 0.5 (10.0) | 1.8 (28.6) | 1.5 (67.5 †) | 0.3 (12.5) |
| Actara™ | 0.3 (5.0) | 5.5 (30.0) | 0.3 (16.7 †) | 0.5 (10.0) |
| Confidor Guard™ | 0 (0) | 2.0 (31.2) | 1.3 (65.0) | 0.5 (33.3 †) |
| SCSI-02 soil | 0.8 (6.3) | 1.5 (24.7) | 0.8 (50.0 †) | 0.8 (25.0) |
| SCSI-03b | 0.3 (1.9) | 4.3 (29.5) | 1.5 (33.3 *) | 2.3 (94.4 *) |
| Dimethoate™ | 0 (0) | 0 (0 *) | 4.3 (80.3 *) | 1.5 (28.6 *) |
| SCSI-01 | 0.3 (3.6) | 0.5 (9.5 *) | 0.8 (20.0 *) | 1.5 (33.3) |
| SCSI-02 foliar | 0 (0) | 0.8 (25.0 *) | 2.3 (61.3) | 0.8 (37.5) |

When calculating percentages replicates with no eggs were omitted:
* average of 3 replicates
† Average of 2 replicates

Other beneficials recorded over the latter part of the trial were: spiders, ladybirds (3 banded, white collared, transverse, minute two-spotted) and pirate bugs. Lacewings, predatory bugs (smudge bug, big eyed bug, brokenbacked bug), predatory beetles (e.g. red and blue beetle) and predatory thrips were also observed occasionally; these were grouped into 'other predators' for the purpose of analysis (Table 79).

Dimethoate had an adverse effect on the majority of the beneficial species, and this was found to be statistically significant on several occasions, particularly towards the end of the trial (Table 79). This may at least partially explain the higher numbers of helicoverpa larvae observed in the dimethoate treatment at 79 DAS. Numbers of beneficials were also significantly lower in the majority of the other insecticide treatments compared to the control at one or more assessments, although this was generally not consistent across assessments or species.

Numbers of ladybirds appeared to be particularly affected by treatment towards the end of the trial, although results were not subjected to statistical analysis as numbers were too low.

Table 79. Mean densities (number/10 plants) of beneficial insects. For each beneficial group, treatment means in the same column sharing a common letter are not significantly different (LSD test at *P* = 0.05). Numbers significantly lower than the control are highlighted in bold.

| Beneficial | Treatment | 57 DAS (04/04/07) | 65 DAS (12/04/07) | 71 DAS (18/04/07) | 79 DAS (26/04/07) |
|---|---|---|---|---|---|
| Spiders | Unsprayed control | 2.0 | 1.5 | 2.8 a | 1.8 ab |
| | Actara™ | 1.0 | 2.8 | 1.2 ab | 2.8 ab |
| | Confidor Guard™ | 2.8 | 3.8 | 2.1 a | 2.9 ab |
| | SCSI-02 Soil | 2.5 | 2.5 | 2.8 a | 4.1 a |
| | SCSI-03b | 1.3 | 1.5 | 2.9 a | 3.6 a |
| | Dimethoate™ | 4.3 | 1.0 | **0.2 b** | **0.2 c** |
| | SCSI-01 | 2.5 | 2.3 | **0.4 b** | 0.9 bc |
| | SCSI-02 Foliar | 2.8 | 1.0 | **0.4 b** | 1.0 bc |
| Ladybirds | Unsprayed control | 1.5 | 0.5 | 0 | 7.8 |
| | Actara™ | 0.3 | 0.5 | 0 | 1.8 |
| | Confidor Guard™ | 0 | 0 | 0 | 1.3 |
| | SCSI-02 Soil | 0.3 | 0 | 1.0 | 0 |
| | SCSI-03b | 0.3 | 0.3 | 0 | 0.3 |
| | Dimethoate™ | 1.8 | 0.5 | 0.3 | 0.3 |
| | SCSI-01 | 1.8 | 0.8 | 0 | 0.8 |
| | SCSI-02 Foliar | 0.5 | 0.8 | 0 | 0.3 |
| Pirate bugs | Unsprayed control | 7.0 | 12.5 | 8.8 | 10.1 ab |
| | Actara™ | 7.3 | 17.8 | 9.3 | 12.7 a |
| | Confidor Guard™ | 3.0 | 10.5 | 10.8 | 8.1 ab |
| | SCSI-02 Soil | 6.5 | 8.8 | 7.8 | 7.6 ab |
| | SCSI-03b | 0.8 | 10.8 | 10.5 | 10.9 ab |
| | Dimethoate™ | 6.8 | 4.0 | 3.3 | **0.7 c** |
| | SCSI-01 | 7.0 | 9.3 | 9.0 | 4.8 b |
| | SCSI-02 Foliar | 3.8 | 7.0 | 11.0 | 8.4 ab |
| Others | Unsprayed control | 2.3 ab | 5.8 a | 4.0 | 3.7 ab |
| | Actara™ | 1.0 bc | **2.0 bcd** | 1.8 | 1.6 bc |
| | Confidor Guard™ | **0.3 c** | 3.7 abc | 4.8 | **0.7 cd** |
| | SCSI-02 Soil | 1.3 abc | 4.1 ab | 4.8 | 6.1 a |
| | SCSI-03b | 1.0 bc | **1.8 cde** | 0.8 | **0.4 cd** |
| | Dimethoate™ | 3.0 a | **0.7 e** | 1.0 | **0 d** |
| | SCSI-01 | 2.5 ab | **1.2 de** | 2.5 | 3.1 ab |
| | SCSI-02 Foliar | 3.0 a | 3.9 ab | 2.0 | 3.6 ab |

Figures 40 to 43. Proportions of each group of beneficial organism

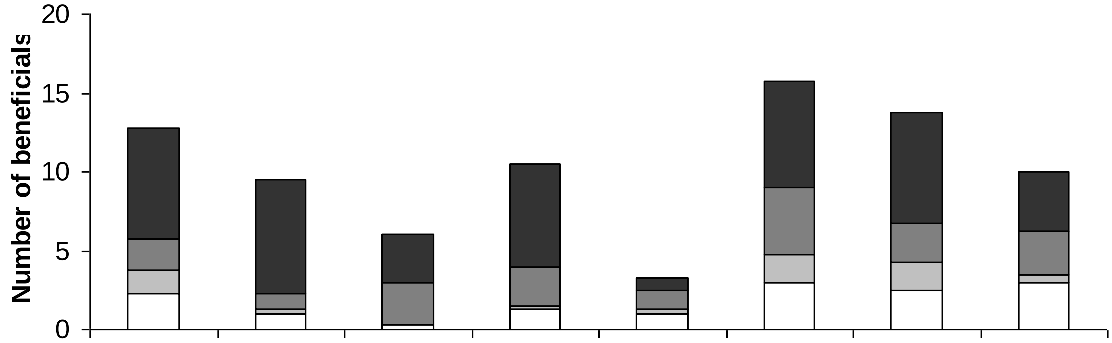



Fig.40 57 DAS

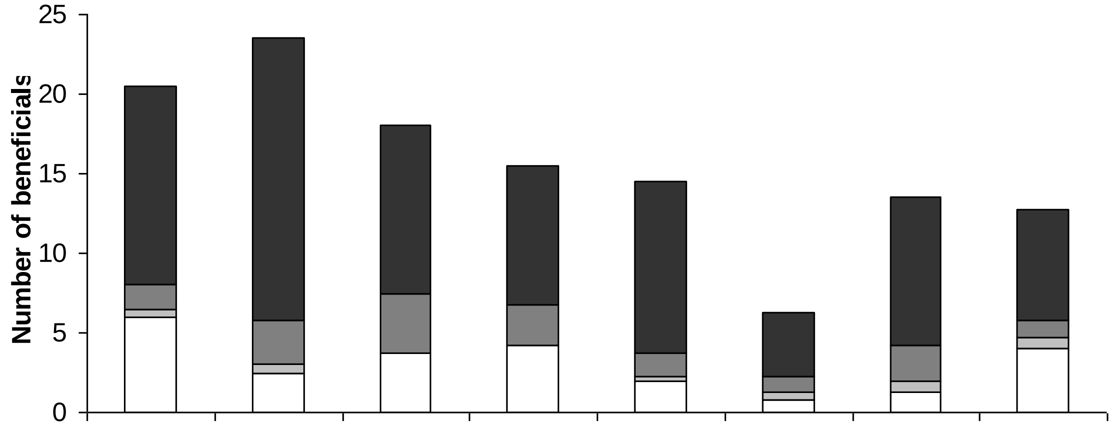



Fig.41 65 DAS

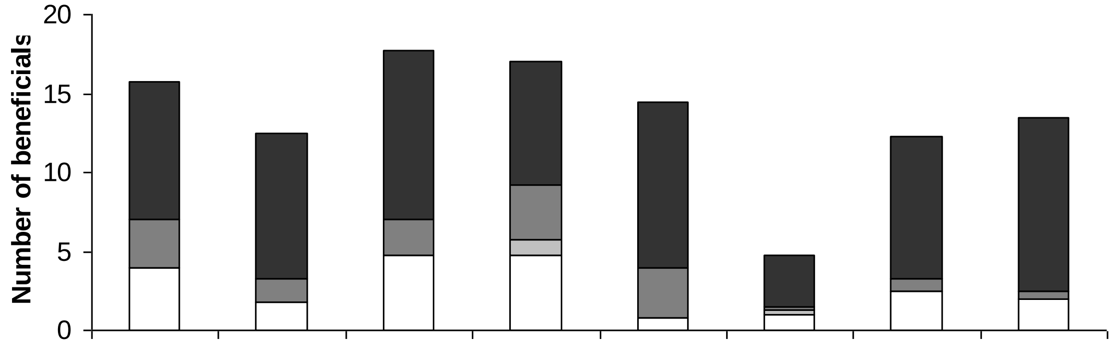



Fig.42 71 DAS

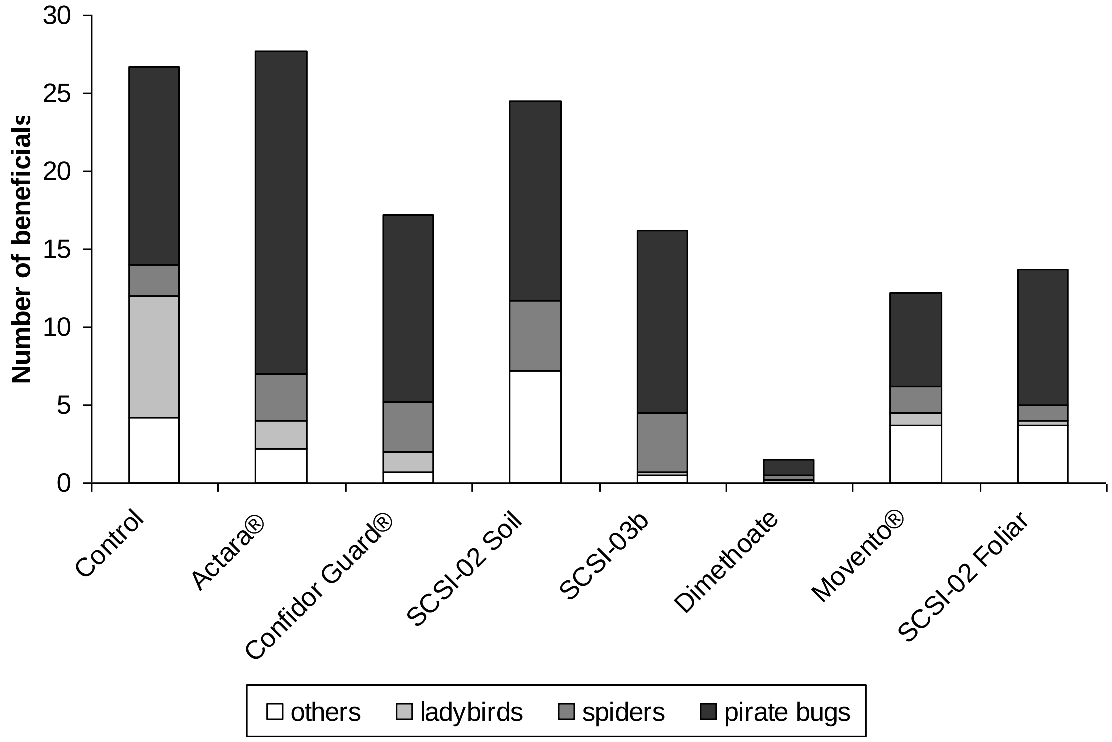



Fig.43 79 DAS

***Sticky traps***

Sticky traps were used as an additional sampling technique from silking to harvest (Table 80). Treatments were found to have a significant effect on numbers of trapped thrips at 71 DAS, with significantly fewer thrips in the Confidor Guard™, dimethoate and SCSI-02 foliar treatments compared to the control. Although thrips numbers were still low in these three insecticide treatments at the following assessment (79 DAS) the control population had declined, and no significant differences amongst treatments were detected. Dimethoate also had a significant effect on numbers of trapped jassids at the 79 DAS assessment only. Too few leafhoppers, flea beetles and aphids were trapped to allow statistical analysis.

Table 80. Mean numbers of pest insects trapped on yellow sticky traps. Treatment means in the same column sharing a common letter are not significantly different (LSD test at $P$ = 0.05). Numbers significantly lower than the control are highlighted in bold.

| Pest | Treatment | 57 DAS (04/04/07) | 65 DAS (12/04/07) | 71 DAS (18/04/07) | 79 DAS (26/04/07) |
|---|---|---|---|---|---|
| Jassids | Unsprayed control | 8.0 | 4.3 | 5.5 | 8.7 ab |
| | Actara™ | 8.0 | 4.5 | 3.5 | 13.3 a |
| | Confidor Guard™ | 7.5 | 2.5 | 4.0 | 8.6 ab |
| | SCSI-02 soil | 5.0 | 6.0 | 6.0 | 9.7 ab |
| | SCSI-03b | 4.3 | 2.3 | 3.0 | 6.4 bc |
| | Dimethoate™ | 9.8 | 3.3 | 3.5 | **4.1 c** |
| | SCSI-01 | 12.3 | 3.0 | 5.5 | 10.3 ab |
| | SCSI-02 foliar | 12.5 | 5.8 | 2.5 | 7.0 bc |
| Thrips | Unsprayed control | 4.5 | 2.3 | 12.5 a | 5.8 |
| | Actara™ | 3.8 | 2.5 | 5.9 abc | 5.5 |
| | Confidor Guard™ | 2.8 | 4.0 | **4.3 bc** | 2.3 |
| | SCSI-02 soil | 2.5 | 4.8 | 5.6 abc | 3.3 |
| | SCSI-03b | 4.3 | 2.0 | 7.4 ab | 7.8 |
| | Dimethoate™ | 5.0 | 1.3 | **1.8 cd** | 1.8 |
| | SCSI-01 | 2.5 | 3.8 | 5.7 abc | 3.0 |
| | SCSI-02 foliar | 2.8 | 2.0 | **1.0 d** | 1.3 |
| Leafhoppers | Unsprayed control | 0.5 | 0.5 | 0.3 | 0 |
| | Actara™ | 0 | 0 | 0.3 | 0.5 |
| | Confidor Guard™ | 0.3 | 0.8 | 0.5 | 0 |
| | SCSI-02 soil | 0 | 0.3 | 0 | 0.3 |
| | SCSI-03b | 0 | 0 | 0.3 | 0.5 |
| | Dimethoate™ | 0.3 | 0.3 | 0 | 0.3 |
| | SCSI-01 | 0 | 0 | 0.5 | 0 |
| | SCSI-02 foliar | 0.5 | 0 | 0.3 | 0.3 |
| Flea beetles | Unsprayed control | 1.3 | 1.0 | 0 | 0.5 |
| | Actara™ | 0.3 | 0 | 0 | 0 |
| | Confidor Guard™ | 1.0 | 0.3 | 0 | 0.3 |
| | SCSI-02 soil | 0.3 | 0.3 | 0 | 0.3 |
| | SCSI-03b | 0.3 | 0 | 0 | 0.3 |
| | Dimethoate™ | 1.3 | 0.3 | 0.3 | 0 |
| | SCSI-01 | 0.5 | 0.5 | 0 | 0.3 |
| | SCSI-02 foliar | 0.8 | 0 | 0 | 0 |
| Aphids | Unsprayed control | 0.8 | 0.3 | 0 | 0 |
| | Actara™ | 0 | 0 | 0 | 1.3 |
| | Confidor Guard™ | 0 | 0 | 0 | 0 |
| | SCSI-02 soil | 0 | 0.3 | 0 | 0 |
| | SCSI-03b | 0.3 | 0 | 0 | 0 |
| | Dimethoate™ | 0.3 | 0 | 0 | 0.3 |
| | SCSI-01 | 0.3 | 0 | 0 | 0 |
| | SCSI-02 foliar | 0.3 | 0.3 | 0 | 0.3 |

There was no effect of treatment on the number of trichogramma wasps caught on the sticky traps (Table 81). Small numbers of other beneficial species were also trapped, summed for the purpose of analysis: pirate bug, spider, tachinid flies, predatory beetle, predatory thrips, transverse ladybird beetle, 3 banded ladybird beetle, black mirid and brown smudge bug. At 65 DAS there were significantly more of these other beneficials trapped in the control treatment than any other treatment except Confidor Guard™. Numbers were too low to allow analysis at 71 or 79 DAS.

Table 81. Mean numbers of trichogramma and other beneficial insects trapped on yellow sticky traps. Treatment means in the same column sharing a common letter are not significantly different (LSD test at *P* = 0.05). Numbers significantly lower than the control are highlighted in bold.

| Beneficial | Treatment | 57 DAS (04/04/07) | 65 DAS (12/04/07) | 71 DAS (18/04/07) | 79 DAS (26/04/07) |
|---|---|---|---|---|---|
| Trichogramma | Control | 1.8 | 0.3 | 1.8 | 1.5 |
| | Actara™ | 3.5 | 1.5 | 1.3 | 1.0 |
| | Confidor Guard™ | 1.8 | 1.0 | 1.0 | 1.8 |
| | SCSI-02 Soil | 2.0 | 1.5 | 1.0 | 0.5 |
| | SCSI-03b | 0.8 | 0.5 | 1.0 | 0.8 |
| | Dimethoate™ | 3.3 | 1.8 | 2.5 | 2.8 |
| | SCSI-01 | 1.8 | 0.8 | 2.3 | 1.8 |
| | SCSI-02 Foliar | 4.3 | 1.5 | 2.3 | 1.3 |
| Other beneficials | Control | 0.8 | 1.5 a | 0.8 | 1.0 |
| | Actara™ | 0.5 | **0.5 bc** | 0.8 | 0.3 |
| | Confidor Guard™ | 1.0 | 1.0 ab | 0.8 | 0.3 |
| | SCSI-02 Soil | 2.3 | **0.5 bc** | 1.3 | 0 |
| | SCSI-03b | 1.3 | **0 c** | 0.3 | 0.3 |
| | Dimethoate™ | 1.5 | **0 c** | 0.5 | 0 |
| | SCSI-01 | 0.8 | **0 c** | 0.5 | 0.3 |
| | SCSI-02 Foliar | 0.8 | **0.3 bc** | 0.5 | 0.3 |

## 5.30 Disease Management – results

**The survey shows that a significant number of diseases are present throughout the industry in Australia**, and that few of these diseases occur extensively throughout the geographic spread of the industry. The best known and most widely distributed of the diseases mentioned were Turcicum leaf blight and Common rust and the general area of soil-borne diseases/establishment problems. These two leaf diseases have occurred in crops in at least some seasons in five of the nine regions surveyed. The remaining diseases specifically occur in only one or two regions.

The widest range of diseases is encountered in the warm, humid sub-tropics and tropics of Qld. Disease severity is also highest in Qld, with the heaviest disease pressure being experienced in Bundaberg.

While the largest effects on production were reported as high as 30%-50% from the effects of Turcicum leaf blight in the Bundaberg area, none of the diseases currently have a major impact on the overall Australian sweet corn production.

The survey revealed that crop scouting was practised in all regions, either via crop consultants, in-house consultants or by growers utilizing their own experience and knowledge of their region. This practice allows early recognition of disease symptoms so that remedial action, such as applying an appropriate fungicide, can be implemented.

The survey indicated that this strategy was adopted in all regions by at least some growers. The frequency of disease occurrence and intensity of fungicide applications reflect the importance of the two leaf diseases mentioned above in the various regions.

**Varieties Grown in Australia**

The number of varieties is very small given the range of climates and environmental conditions experienced through the surveyed areas.

The variety most widely grown, Goldensweet Improved, enjoys a high level of market acceptance and produces well over a wide range of environments. This is dependent upon growers selecting the period of least Turcicum blight pressure as the variety has a low level of tolerance to this disease.

### 5.31 Australian Survey – Sweet Corn Diseases.

The following are the range of Diseases reported in a survey of growers in the major production districts through Queensland, New South Wales, Victoria, Western Australia and Tasmania :-

Turcicum leaf blight or Northern leaf blight - *Exserohilum turcicum*
Rust or Common rust - *Puccinia sorghi*
Yellow leaf blight (unknown causal organism, but possibly Southern leaf blight or Maydis leaf blight) - *Bipolaris maydis*
Charcoal rot or Ashy stem blight - *Macrophomina phaseolina*
Boil Smut or Common smut - *Ustilago zeae*
Wallaby ear – initially thought to be a virus infection, but now known to be from a toxin injected by leafhoppers while feeding. Causes stunting and stiffening of plants.
Plants grow away when leafhoppers are controlled.
Mosaic - Johnson Grass Mosaic Virus (JGMV)
Soil-borne diseases - various fungi (e.g. fusarium, pythium, rhizoctonia)
Nematodes, root lesion nematodes - *Pratylenchus zeae*

The current regional distribution, severity and techniques growers use to manage these diseases are presented in Table 82. All production, with the exception of the NSW processing crops and 10% of the SEQ production, was for the fresh market.

**Table 82:** ***Sweet corn diseases distribution, severity and management***

| **Region** | **Incidence and Severity** | **Management Methods** reported by growers |
|---|---|---|
| ***DISEASE*** | **Turcicum Leaf Blight** ***(Exserohilum turcicum)*** | |
| North Queensland (Bowen-Burdekin) | Occurs every season and causes minor yield losses of less than 5%. Disease pressure is highest in the autumn-winter period and higher in the Burdekin area than in the Bowen area. | Spray crops with fungicides chlorothalonil (e.g. Bravo™), or occasionally propoconazole (Tilt™).<br>Growers select varieties with highest resistance for highest pressure periods. |
| Central Qld (Bundaberg) | Occurs every season and causes yield losses in the vicinity of 30% – 50%. The disease is present throughout the growing season. | Apply fungicide sprays of chlorothalonil at 10 day intervals.<br>Selecting the most resistant varieties for the highest pressure period is a practice. |
| South-east Qld (Lockyer-Fassifern Valleys, Eastern Darling Downs) | Only occasional problem, causes less than 1% yield loss. | 50% of growers apply chlorothalonil when weather is conducive or disease is prevalent.<br>Growers use variety with high resistance for summer harvests and least resistant in early spring sowings. |
| NSW Sydney Basin | Occurs 1 season in 3 and causes yield losses of less than 10% in those seasons. Accounts for 30% of disease problems in this region. | Not usually sprayed for but when severe 20% of growers spray 1-2 times. Use chlorothalonil or propoconazole.<br>Growers use more susceptible varieties early in season (autumn) and the more tolerant later. |
| NSW processing Cowra-Bathurst | Not considered a problem | |
| Victoria | Not considered a problem | |
| Victoria – Lindenow district | Not considered a problem | |
| Tasmania | Not considered a problem | |
| Western Australia | Rarely or never a problem, but when it occurs yield losses of 20-30% result. | All growers indicated they select varieties with resistance to diseases. |

| **Table 82 (cont)**<br>**Region** | **Incidence and Severity** | **Management Methods**<br>reported by growers |
|---|---|---|
| ***DISEASE*** | **Common Rust (*Puccinia sorghi*)** | |
| North Queensland<br>(Bowen-Burdekin | Only a problem in some minor varieties used for niche markets. Occurs more in the Burdekin area than Bowen. | When it occurs, controlled by propoconazole when used for leaf blight. Restriction with 28 day withholding period. Select varieties with resistance where possible. |
| Central Qld<br>(Bundaberg) | Mentioned as a leaf disease occurring but no details are mentioned. | Sprays with sulphur at the same frequency as chlorothalonil for leaf blight which would provide control.<br>Variety selection used probably eliminates rust as a problem |
| South-east Qld<br>(Lockyer-Fassifern Valleys, Eastern Darling Downs. | Not considered a problem | |
| NSW Sydney Basin | Not considered a problem | |
| NSW processing<br>Cowra-Bathurst | Mentioned by a third of growers as a leaf disease, but rarely or never seen overall. When it occurs, yield losses of less than 10% are estimated to occur. | All growers indicate that when the disease occurs they spray to control it. The only fungicide mentioned is chlorothalonil. Varieties and sowing schedules are selected by the processors. |
| Victoria | For 20% of growers, rust occurs 1 season in 5 or less, while 80% never or rarely see it. When it occurs, yield losses are estimated at less than 5%. | Only 10% of growers need to spray to control the disease. Growers who experience the disease choose resistant varieties.<br>Most growers don't need to undertake any specific management for rust control. |
| Victoria – Lindenow district | Growers experience rust 1 year in 5 or less with yield losses when it occurs at less than 5%. | Fungicide sprays are used when necessary (propoconazole). Growers choose varieties with best tolerance to rust. |
| Tasmania | Not considered a problem | Uses plastic mulch and trickle irrigation to reduce opportunity for leaf diseases. |
| Western Australia | Not considered a problem | |

| Table 82 (cont)<br>Region | Incidence and Severity | **Management Methods**<br>reported by growers |
|---|---|---|
| ***DISEASE*** | **Yellow Leaf Blight (probably Southern leaf blight - *Bipolaris maydis)*** | |
| North Queensland Bowen-Burdekin | Occasional disease, occurs 1 season in 5, mostly in the Burdekin area in early and mid season. Only reported in NQ in the survey. | No management techniques available specifically for this disease. |
| ***DISEASE*** | **Charcoal Rot, Ashy stem blight *(Macrophomina phaseolina)*** | |
| North Queensland Bowen-Burdekin | Sporadic disease in the Burdekin area late in the season. Occurs as a rot in the tassel and sometimes as a stem disease. Only reported in NQ in the survey. | Disease is exacerbated by stress factors. Try to manage stress effects in harsher seasons. |
| ***DISEASE*** | **Boil Smut, Common Smut *(Ustilago zeae)*** | |
| South-east Qld (Lockyer-Fassifern Valleys, Eastern Darling Downs | Increasing problem especially when conditions are moist. Worst disease problem in this region. Occasionally a stem rot causing less than 1% loss, but most often a cob rot causing less than 5% loss but contaminates packing shed machinery. | No specific management techniques available. |
| NSW Sydney Basin | Causes less than 10% yield loss 1 season in 3. Accounts for 70% of disease problems in this region. Only reported in SEQ and the Sydney basin in this survey. | No specific management techniques available. |
| ***DISEASE*** | **Wallaby Ear** | |
| South-east Qld (Lockyer-Fassifern Valleys, Eastern Darling Downs<br>. | An occasional problem which can severely stunt plants if not managed and potentially reduce yields. Severity of the disease (toxin affect) depends on the leafhopper numbers on the plant. | Controlling the leafhopper vector (*Cicadulina bimaculata)* will eliminate the disease as the insect needs to be continually feeding on the plant to cause the effects. Dimethoate sprays are used to control the pest but the chemical is very disruptive to IPM programs due to its effect on beneficial insects. |
| ***DISEASE*** | **Mosaic - *Johnson Grass Mosaic Virus* (JGMV)** | |
| South-east Qld (Lockyer-Fassifern Valleys, Eastern Darling Downs | Very susceptible hybrids show extensive yellowing and early infection often results in severe stunting and yield reduction. Aphid transmitted virus, the main host being Johnson grass. Also survives in stand-over forage and grain sorghum crops. Does not cause yield losses due to well known management practices. | Growing a resistant hybrid for mid-summer harvests (processing and fresh market) |

| Table 82 (cont) Region | Incidence and Severity | Management Methods reported by growers |
|---|---|---|
| ***DISEASE*** | **General - Soil-borne diseases, other diseases.** | |
| North Queensland | Overall, soil diseases occur rarely. Fusarium and nematodes have been identified sporadically in the past. | Most sweet corn growers use a crop rotation system as a preventative measure. |
| South-east Qld. | Occasional seedling establishment problems caused by rhizoctonia. Less than 1% losses. | Use crop rotations. |
| NSW-Sydney Basin | Occasional establishment problems in cooler seasons. | Crop rotations are normal part of crop management practices. |
| NSW-processing | No problems encountered. | Two-thirds of growers indicate use of crop rotations from year to year. Others appear to grow sweet corn on same ground each year. |
| Victoria | No problems mentioned. | No information on crop rotations. |
| Victoria-Lindenow | Some establishment problems recorded but non specific.<br>Experience cob disease problems but no details given. | Rotate sweet corn with other vegetable crops.<br>No practices mentioned. |
| Tasmania | Establishment problems mentioned but no specifics. | No cropping details given. |
| Western Australia | No problems encountered. | Rotate corn with other vegetables. |

The data gathered indicates that, while a significant number of diseases are present throughout the industry in Australia, few of the diseases mentioned by growers in the survey occur extensively throughout the geographic spread of the industry. The best known and most widely distributed of the diseases mentioned were *Turcicum leaf blight* and *Common rust* and the general area of soil-borne diseases/establishment problems (which in many cases may be due to soil insects as such problems are difficult to diagnose). The two leaf diseases have occurred in crops in at least some seasons in five of the nine regions surveyed. Combining the occurrence of the two leaf diseases indicates that at some stage all regions have experienced infections of at least one of these two diseases. The remaining diseases specifically occur in only one or two regions.

The widest range of diseases are encountered in the warm, humid sub-tropics and tropics of Qld. Disease severity is also highest in Qld, with the heaviest disease pressure being experienced in Bundaberg. A similar pattern emerged in an earlier sweet corn project, VG436, where *Turcicum leaf blight* was frequently observed in varieties which rarely succumbed to this disease in either the Lockyer Valley in SEQ or the Bowen-Burdekin area in NQ.

While the largest effects on production were reported as high as 30%-50% from the effects of *Turcicum leaf blight* in the Bundaberg area, none of the diseases currently have a major impact on the overall Australian sweet corn production. A key to this is the range of management practices available to growers to manage these diseases. Integral to these practices is the widespread adoption of Integrated Pest Management (IPM).

The survey revealed that crop scouting was practised in all regions, either via crop consultants, in-house consultants or by growers utilizing their own experience and knowledge of their region. This practice allows early recognition of disease symptoms so that remedial action, such as applying an appropriate fungicide, can be implemented. The survey indicated that this strategy was adopted in all regions by at least some growers. The frequency of disease occurrence and intensity of fungicide applications reflect the importance of the two leaf diseases mentioned above in the various regions.

***Varieties Grown***

That little impact on sweet corn production is experienced from disease infestations is a reflection on how well variety selection has been adopted by growers in implementing their IPM systems. It also reflects how well breeding programs have been able to incorporate resistance to several diseases common in Australia which, particularly in the temperate areas of the country all but remove the necessity to apply fungicides.

The range of sweet corn varieties currently grown through Australia in the regions surveyed are listed in Table 2. The number of varieties is very small given the range of climates and environmental conditions experienced through the surveyed areas. This is possibly a response to market demand for a particular style of product rather than the varieties being particularly well adapted to such a wide range of environmental conditions.

**Table 83:** ***Sweet corn varieties by region.***

| Region | Varieties Grown | Usage Comments |
|---|---|---|
| North Queensland (Bowen-Burdekin) | Goldensweet Improved.<br><br><br>Lancaster, Sentinel, Gladiator.<br>Hibrix.<br><br><br>Crunch, Samurai, Everest. | Major variety grown due to market preference but no visible improvement observed in Turcicum blight resistance over *Goldensweet.*<br>Used instead of *Goldensweet Improved* during periods when Turcicum blight threatens.<br>*Hibrix* used in late season when conditions become harsh. More usage of these alternatives in the Burdekin area where disease pressure is highest.<br>Minor varieties (bicolours, white) grown for niche markets. Also have the least resistance to leaf diseases. |
| Central Qld (Bundaberg) | Goldensweet Improved,*<br>Lancaster, Gladiator. | Lancaster and Gladiator are both preferred over Goldensweet Improved for their higher level of resistance to Turcicum blight. (Market preference requires production of Goldensweet Improved.) |
| South-east Qld (Lockyer-Fassifern Valleys, Eastern Darling Downs) | Hibrix.<br><br><br>Goldensweet Improved.<br><br><br>Sundry other new varieties for grower trials. | Tropical variety grown for mid-summer harvests (processing and fresh) for its JGMV resistance and ability to withstand harsh summer conditions.<br>Used for early spring sowings (fresh market only) when JGMV not prevalent. Higher yielding than Hibrix in this period but more prone to Turcicum blight.<br>Looking for varieties with good cob quality and better disease resistance to reduce production risk. |
| NSW Sydney Basin | Goldensweet Improved.<br><br>Magnum,<br>Max, Matador | Planted early in season (October-Nov) during period of least Turcicum blight pressure.<br>These more tolerant varieties planted later in the season when Turcicum blight pressure is higher. Max is a popular variety in this region. |
| NSW processing Cowra-Bathurst | Punch, Jubilee, Basin, Sovereign. | Processing varieties chosen by processor, as is the sowing schedule. |
| Victoria | Goldensweet Improved*, Rising Sun. | Rust is the only leaf disease of concern listed by these growers and both these varieties have good resistance to rust. |
| Victoria – Lindenow district | Goldensweet Improved, Gladiator, Rising Sun, Crunch, Obsession. | With rust being the leaf disease of concern, the suite of varieties chosen (with the exception of *Crunch*) should be quite resistant to rust. |
| Tasmania | Snosweet. | Only establishment problems mentioned. Use of trickle irrigation may reduce disease pressure. |
| Western Australia | Goldensweet Improved *. | Only variety mentioned |

* While Goldensweet was listed in the survey, it is no longer available and has been replaced by *Goldensweet Improved*

The variety most widely grown, *Goldensweet Improved*, enjoys a high level of market acceptance and produces well over a wide range of environments. This is dependent upon growers selecting the period of least *Turcicum blight* pressure as the variety has a low level of tolerance to this disease. The cob types and leaf disease tolerances of the varieties listed are illustrated in Table 84.

**Table 84:** ***Cob types and leaf disease tolerance of varieties from the survey***

| Variety | Cob Type | Turcicum Blight Rating (1-5) | Common Rust Rating (1-5) | Company | End Use |
|---|---|---|---|---|---|
| Goldensweet Improved | Yellow Supersweet | 2 | 5 | Snowy River, Lefroy Valley | Fresh Market |
| Lancaster | Yellow Supersweet | 3 | 5 | Snowy River, Lefroy Valley | Fresh Market |
| Sentinel | Yellow Supersweet | 5 | 5 | Sunland seeds | Fresh Market |
| Gladiator | Yellow Supersweet | 4 | 5 | Snowy River, Lefroy Valley | Fresh Market |
| Hibrix | Yellow Supersweet | 3 | 5 | Pacific seeds | Fresh Market & Processing |
| Punch | Yellow Normal (sugary) | 2 | 3 | Snowy River, Lefroy Valley | Fresh Market & Processing |
| Jubilee | Yellow Normal (sugary) | 1 | 2 | Syngenta | Processing |
| Basin | Yellow Supersweet | 2 | 5 | Seminis | Fresh Market & Processing |
| Sovereign | Yellow Supersweet | 5 | na | Syngenta | Fresh Market & Processing |
| Max | Yellow Supersweet | 4 | 5 | Sunland seeds | Fresh Market |
| Magnum | Yellow Supersweet | 1 | 3 | Syngenta | Fresh Market |
| Matador | Yellow Supersweet | 4 | 5 | Snowy River, Lefroy Valley | Fresh Market |
| Rising Sun | Yellow Supersweet | 2 | 5 | Snowy River, Lefroy Valley | Fresh Market |
| Snosweet | Yellow Supersweet | 5 | na | Snowy River, Lefroy Valley | Fresh Market |
| Crunch | Bicolour Supersweet | 4 | 2 | Snowy River, Lefroy Valley | Fresh Market |
| Samurai | Bicolour Supersweet | 3 | 5 | Snowy River, Lefroy Valley | Fresh Market |
| Obsession | Bicolour Supersweet | 3 | 5 | Seminis | Fresh Market |
| Everest | White Supersweet | 2 | 3 | Snowy River, Lefroy Valley | Fresh Market |

Diseases are rated 1-5 where:

1 = Susceptible
2 = Moderately susceptible
3 = Moderate
4 = Moderately tolerant
5 = Tolerant

na = not available

Table 43 and Key adapted from varietal information data sheets from Lefroy Valley Seed Co., Sunland Seeds and Seminis Vegetable Seeds.

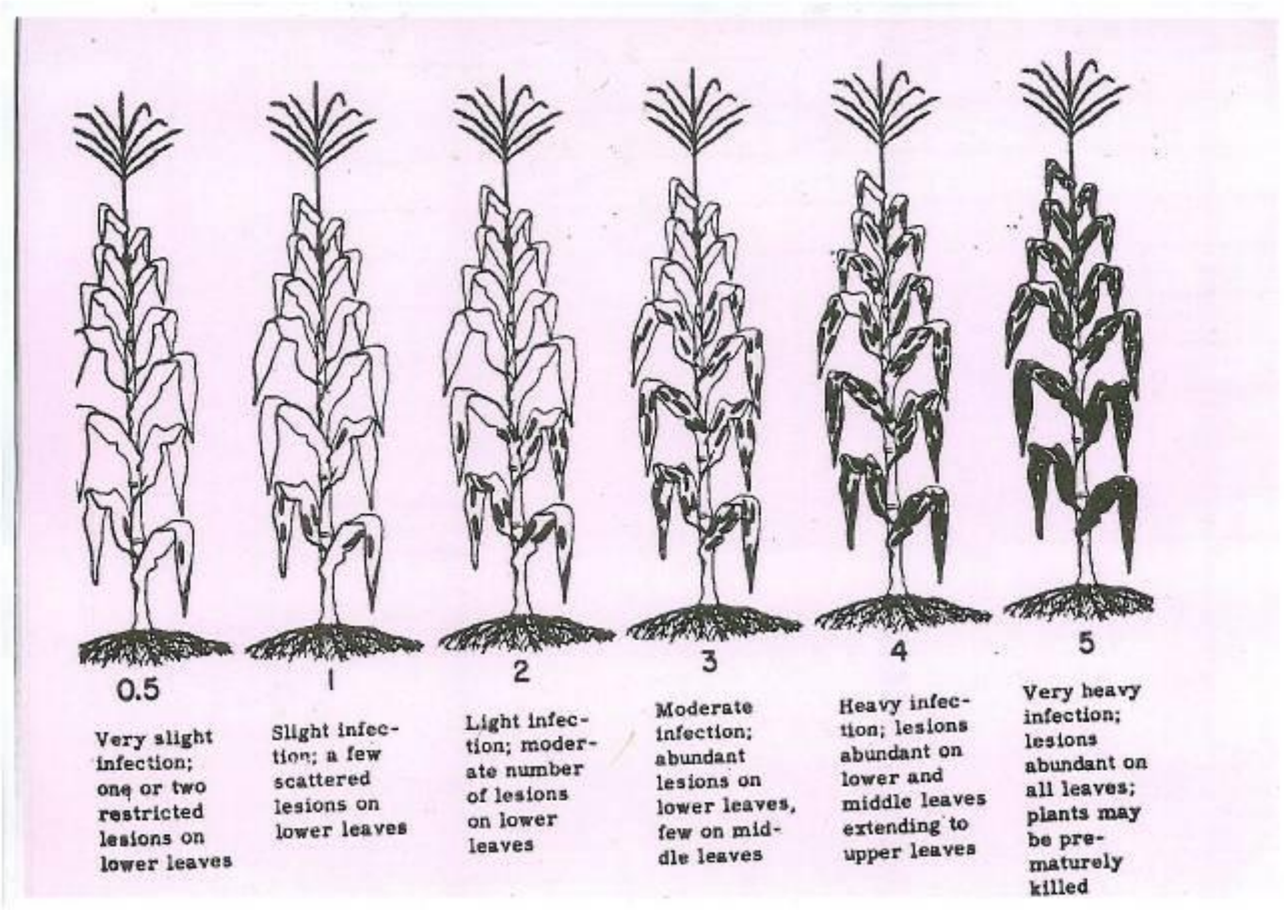
## 5.32 North Queensland - Results

Table 85: Disease Severity ratings (0-5 scale) for Turcicum and Yellow Leaf Blight in sweet corn varieties at Bowen Research Station. (rating scale – Fig 44)

| | | Turcicum | | | Yellow Leaf Blight | | | Turcicum Rating from Table 12 or other sources |
|---|---|---|---|---|---|---|---|---|
| **Company** | **Variety** | *Rep A* | *Rep B* | ***Mean*** | *Rep A* | *Rep B* | ***Mean*** | |
| DPI&F | TSS1 | 0.5 | 0.5 | 0.5 | 1 | 1.5 | 1.25 | n.a. |
| DPI&F | TSS2 | 0 | 0.5 | 0.25 | 1 | 1.5 | 1.25 | n.a. |
| DPI&F | TSS3 | 0 | 0.5 | 0.25 | 2 | 0.5 | 1.25 | n.a. |
| DPI&F | TSS4 | 0 | 0 | 0 | 1.5 | 1.5 | 1.5 | n.a. |
| DPI&F | TSS5 | 0 | 0.5 | 0.25 | 0.5 | 1 | 0.75 | n.a. |
| DPI&F | TSS6 | 0.5 | 0 | 0.25 | 2 | 1 | 1.5 | n.a. |
| Sunland | Sentinel | 0 | 0 | 0 | 0.5 | 1 | 0.75 | Tolerant |
| Sunland | Max | 0.5 | 0.5 | 0.5 | 2 | 1.5 | 1.75 | Mod. Tolerant |
| Sunland | Suregold | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | n.a. |
| Sunland | Polaris Bicolour | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | n.a. |
| Snowy River | Golden Sweet Impr. | 0.5 | 0.5 | 0.5 | 1 | 0.5 | 0.75 | Mod. Susceptible |
| HSR | Lancaster | 0 | 0.5 | 0.25 | 1 | 0.5 | 0.75 | Moderate |
| Lefroy Valley | HY 579 OK | 0.5 | 0 | 0.25 | 0.5 | 1 | 0.75 | Mod. Tolerant |
| Lefroy Valley | HY 1790 OL | 0 | 0 | 0 | 0.5 | 1 | 0.75 | Moderate |
| Lefroy Valley | HY 1481 OM | 0 | 0 | 0 | 0.5 | 0.5 | 0.5 | Mod. Tolerant |
| Lefroy Valley | HY 1516 OM | 0.5 | 0 | 0.25 | 0.5 | 0.5 | 0.5 | Mod. Tolerant |
| Lefroy Valley | HB 2630 OM | 0.5 | 0 | 0.25 | 1 | 2.5 | 1.75 | n.a. |
| Jarit | Crackerjack | 1 | 0.5 | 0.75 | 1.5 | 0.5 | 1 | Mod. Tolerant |
| Jarit | Firestar | 0 | 0.5 | 0.25 | 1.5 | 1 | 1.25 | Moderate |
| Jarit | JTS208 | 0 | 0 | 0 | 1 | 1 | 1 | n.a. |
| Jarit | JTS209 | 0.5 | 1 | 0.75 | 1 | 0.5 | 0.75 | n.a. |
| Jarit | JTS215 | 1 | 2 | 1.5 | 1.5 | 0.5 | 1 | n.a. |
| Jarit | JTS228 | 1 | 1 | 1 | 2 | 1 | 1.5 | n.a. |
| Syngenta | GSS 6352 | 0 | 1 | 0.5 | 3 | 2.5 | 2.75 | n.a. |
| Syngenta | GSS 9372 | 0.5 | 1 | 0.75 | 1 | 1 | 1 | Mod. Susceptible |
| Seminis | Obsession | 1 | 0 | 0.5 | 0.5 | 0.5 | 0.5 | Moderate |
| Seminis | Passion | 0 | 0.5 | 0.25 | 0.5 | 0.5 | 0.5 | Moderate |

A subsample of 4-5 plants from within each plot was rated for disease severity on 31/10/07. The disease ratings based on a 0-5 scale – Fig 44.

Figure 44 – Disease Rating Scale




All the varieties had relatively low disease severity for both Turcicum and Blotch, however the scores were the same or slightly higher for Blotch.

Rust pustules were observed on leaves of varieties HY 570 OK (Lefroy Valley) and GSS 6352 (Syngenta)

## 5.4 Toxicity of three "soft options" insecticides against a range of beneficials – Results.

**In laboratory and semi-field trails, Movento™ had nil or a minor impact on the beneficials tested; Belt™ and SCLI-02 varied from a moderate to nil impact; and *Trichogramma* was not impacted by any of these three 'soft options'.**

The aim of this study was to determine the effect of chlorantraniliprole, flubendiamide and spirotetramat on species representative of the Coccinellidae (*Coccinella transversalis* Fabricius) - Transverse ladybird; *Cryptolaemus montrouzieri* Mulsant)- Mealybug predator, Neuroptera (*Mallada signata* (Schneider)) - Green Lacewing and Chalcidoidea (*Trichogramma pretiosum* Riley) - Helicoverpa parasite.

With the exception of *C. montrouzieri*, all naturally occur in sweet corn in Australia and are effective biological control agents whose preservation is important in IPM. *T. pretiosum* is also released innundatively for the control of heliothis.

***Cryptolaemus montrouzieri***

***Toxicity Bioassay***

There were no significant differences between blocks ($P$>0.5). A two-way ANOVA on the effects of various insecticides at different application rates on the mortality (%) of *C. montrouzieri* adults indicated no significant interaction between insecticide application rates ($F$=1.52, df=2, $P$= 0.56). However, the mean (n=15) mortality (%) of *C. montrouzieri* (adults) after exposure to the various insecticidal treatments were not equal ($F$=46.11, df=4, $P$<0.001). Whilst exposure to spirotetramat residues had no effect on mortality, exposure to deltamethrin, spinosad, chlorantraniliprole and flubendiamide significantly increased mortality (Figure 45).

**Figure 45: Mean mortality (%) of *Cryptolaemus montrouzieri* (adult) after 96h exposure to various insecticides. Treatments with the same letter indicate that means do not differ at *P* = 0.05**

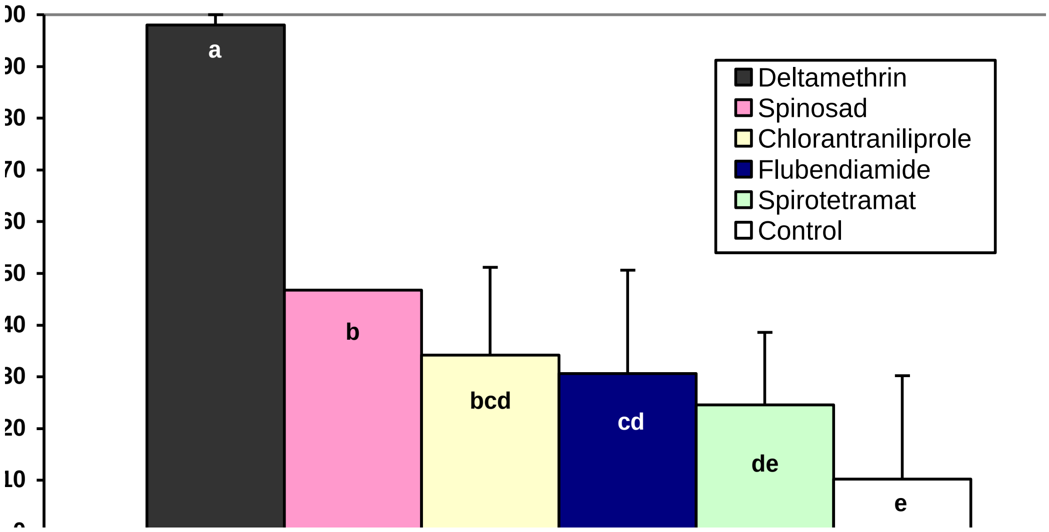


**Table 86. IOBC classification of insecticides based on bioassays**

| Treatment | IOBC |
|---|---|
| Deltamethrin | 4 |
| Spinosad | 2 |
| Chlorantraniliprole | 2 |
| Flubendiamide | 2 |
| Spirotetramat | 1 |
| Control | 1 |

According to the IOBC classification system, spirotetramat is regarded to be harmless (category 1), with no further testing required (Table 86). Flubendiamide, chlorantraniliprole and spinosad were rated as slightly harmful (category 2) and deltamethrin as harmful (Table 86).

### *Semi-field Trial*

A general linear regression analysis of mortality (%) of *C. montrouzieri* (adults) indicated a significant difference between the control and insecticide treatments ($P < 0.001$). The responses to spinosad and flubendiamide did not differ and these were classified as harmless to *C. montrouzieri*. Chlorantraniliprole was found to be slightly harmful, whereas deltamethrin was harmful resulting in 100% mortality (Figure 46).

**Figure 46: Mean mortality (%) of *Cryptolaemus montrouzieri* (adults) following 96h exposure to various insecticides. Treatments with the same letter indicate that means do not differ at *P* = 0.05.**

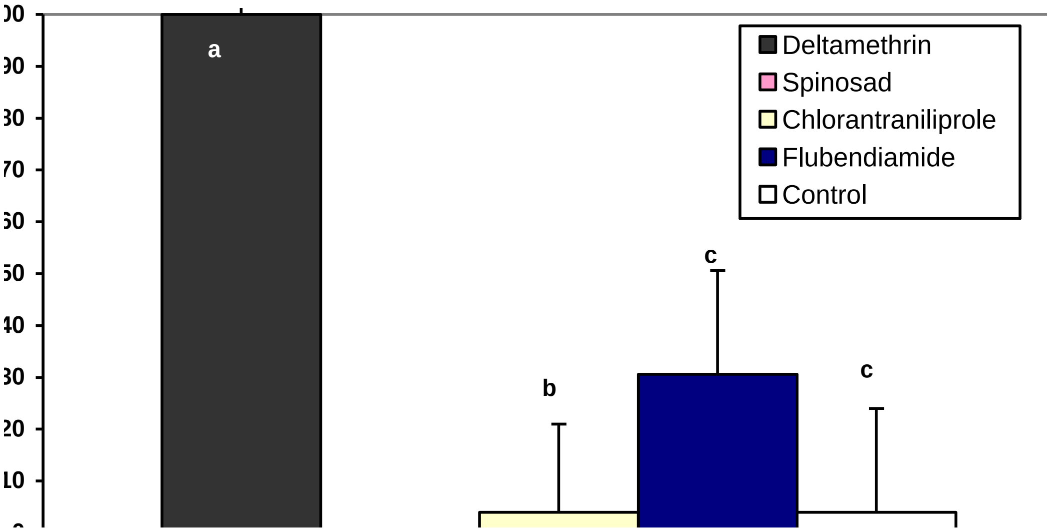


**Table 87: IOBC rating of insecticides based on semi-field trial results**

| Treatment | IOBC classification |
|---|---|
| Deltamethrin | 4 |
| Chlorantraniliprole | 2 |
| Flubendiamide | 1 |
| Control | 1 |
| Spinosad | 1 |

### *Coccinella transversalis*

The mortality of adult *C. transversalis* to various insecticides is shown in Figure 47. Following the IOBC classification system, deltamethrin was the only insecticide classified as highly harmful (category 4), causing 88% mortality. Spinosad was slight harmful (30% mortality; Table 88).

**Figure 47: Mean mortality (%) of (adult) *Coccinella transversalis* following 96h exposure to various insecticides (untransformed means).**

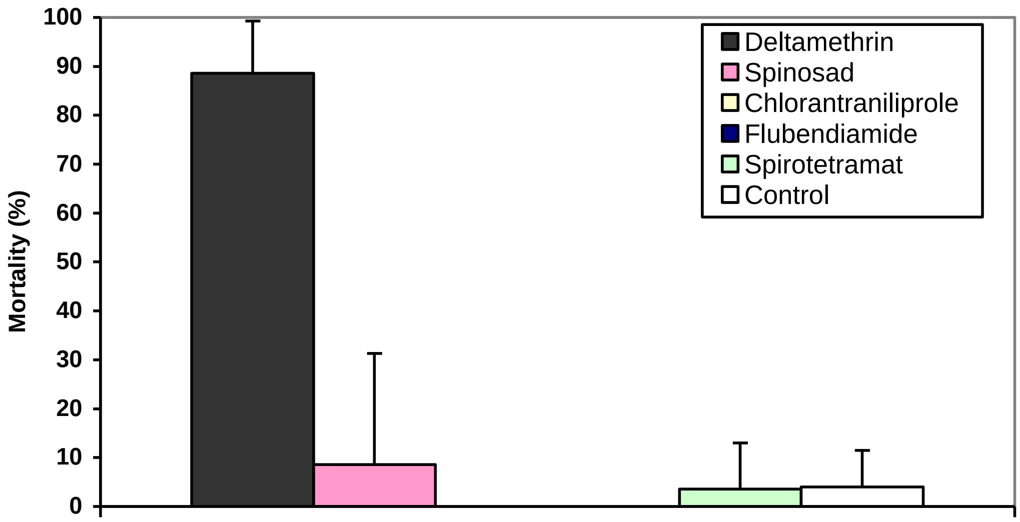



**Table 88. IOBC rating of insecticides based on bioassay for *Coccinella transversalis***

| Treatment | IOBC classification |
|---|---|
| Deltamethrin | 4 |
| Chlorantraniliprole | 1 |
| Flubendiamide | 1 |
| Spirotetramat | 1 |
| Control | 1 |
| Spinosad | 2 |

### *Mallada signata*

#### *Toxicity Bioassay*

There were no differences between blocks with respect to mortality ($P$>0.05). A two-way ANOVA indicated no significant interaction between application rate and insecticide ($F$=1.33, df=2, $P$=0.27). However, mean mortality (%) of first instar *Mallada signata* varied between insecticides ($F$=51.4, df=4, $P$<0.001). Mortality (%) was significantly higher after exposure to all insecticides when compared to the control. Spinosad and deltamethrin were most toxic to larvae, with restored means of 100% and 99.6% respectively. Mortality was next highest from exposure to spirotetramat (83.7%), followed by chlorantraniliprole (69.2%) and flubendiamide (65.1%), which did not significantly differ from each other.

Following the IOBC classification system, flubendiamide and chlorantraniliprole were classified as slightly harmful (category 2), spirotetramat was moderately harmful (category 3), whilst spinosad and deltamethrin were harmful (category 4).

**Table 89: Mean mortality (%) of *Mallada signata* (1st instar) following 96h exposure to various insecticides (transformed means shown). Numbers followed by the same letter indicate that means do not differ (α = 0.05).**

| Treatment | Transformed means | Restored means | IOBC |
|---|---|---|---|
| Spinosad | 90a | 100 | 4 |
| Deltamethrin | 86.3a | 99.6 | 4 |
| Spirotetramat | 66.2b | 83.7 | 3 |
| Chlorantraniliprole | 56.3c | 69.2 | 2 |
| Flubendiamide | 53.8c | 65.1 | 2 |
| Control | 32d | 28.1 | 1 |

**Pupation and adult emergence**

There were no differences between blocks with respect to the time taken for larvae to pupate, or adults to emerge (*P*>0.05). A two-way ANOVA of the number of days taken for larvae to pupate showed that all insecticides, except spinosad, increased the length of the larval stage (*F*=3.55, df=4, *P*=0.02). The time taken for adults to emerge also varied between insecticides (*F*=3.55, df=4, *P*=0.02). Larvae exposed to chlorantraniliprole took significantly longer to emerge than the control and other insecticides, with three individuals failing to emerge. Though larvae exposed to spinosad also took longer to emerge (25.9 days), the difference was not significantly different compared to the control (Table 90). Two larvae exposed to spinosad emerged, but died.

**Table 90. Time (days) taken for *M. signata* larvae to pupate and adults to emerge after exposure to various insecticides applied at recommended field rates and IOBC rating.**

| Treatment | Time taken for | Time taken for | Mortality | IOBC |
|---|---|---|---|---|
| Spinosad | 3.43ab | 25.9ab | 30% | **2** |
| Spirotetramat | 4.71b | 15.1a | 0 | **1** |
| Chlorantraniliprole | 5.14b | 27.1b | 43% | **2** |
| Flubendiamide | 4.86 | 15.7a | 0 | **1** |
| Control | 2.29a | 16.7a | 0 | **1** |

**Semi-field trial**

A general linear regression analysis of the mortality (%) of second instar *M. signata*, assessed after 120 hours, did not significantly differ between insecticides (p = 0.498, α = 0.05).

***Trichogramma pretiosum***

Successful eclosion (%) of adult *T. pretiosum* from moth host eggs was assessed after 144 hours. A two-way ANOVA showed no significant interaction between insecticide rates (*F*=1.59, df=2, *P*=0.212), indicating a similar response pattern for insecticides applied at different application rates. However, eclosion (%) of adult *T. pretiosum* differed with insecticide (*F*=233.15, df=4, *P*<0.001). Of the five insecticides tested, eclosion (%) of adult *T. pretiosum* was significantly reduced after exposure to spinosad and deltamethrin when compared with the control, with a 91.4% and 18.3% reduction in eclosion respectively (Figure 5). Exposure to flubendiamide, spirotetramat or chlorantraniliprole did not significantly reduce eclosion of adult *T. pretiosum*.

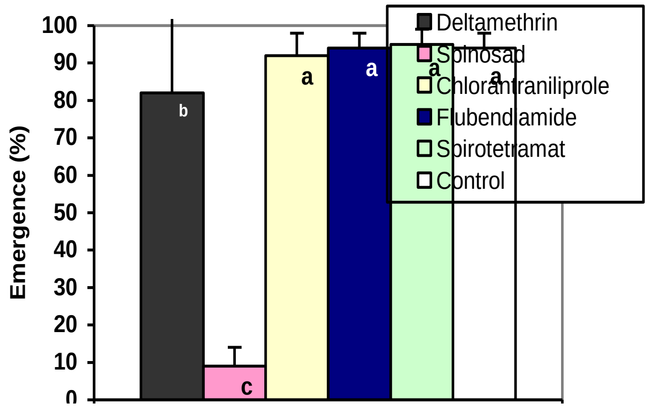



**Figure 48: Mean emergence (%) of *Trichogramma pretiosum* after 144 hour exposure to various insecticides. Like letters indicate means that do not differ (α = 0.05).**

**Table 91: IOBC rating of insecticides based on bioassay for *T. pretiosum***

| Treatment | IOBC classification |
|---|---|
| Flubendiamide | 1 |
| Spirotetramat | 1 |
| Chlorantraniliprole | 1 |
| Control | 1 |
| Deltamethrin | 1 |
| Spinosad | 3 |

According to the IOBC classification system, only spinosad was considered moderately harmful (category 3), with the remaining insecticides classified as harmless.

## Disclaimer:

***A range of insecticides are referred to in this report. Where an insecticide is named together with ™ as a superscript, this refers to the insecticides' Registered Trade Name. This DOES NOT imply that this insecticide is registered for use on sweet corn in Australia. It is important that the registration status of all insecticides are verified prior to their application to sweet corn in Australia.***

# 6.00 Discussion

## 6.10 Soft Options Assessment - Discussion.

**The R&D work program has demonstrated that four (4) additional 'soft options' insecticides have potential for an IPM 'fit'**, and registration of these products should continue to be pursued on behalf of the Australian sweet corn industry. They also appear to have minimal impact on beneficial arthropods, with no affect on *Trichogramma* populations.

- Two (2) new sap sucking pests 'soft options', Movento™ and SCSI-03b (no trade name allocated) were effective against sucking insects (thrips and aphids) and one (1) miticide, Paramite™, has suppressed 2-spotted spider mite populations. These new insecticides and miticide do appear to have minimal impact on beneficial arthropods, although they do not appear to affect *Trichogramma* populations.
- Belt™ and Coragen™ are very effective against Helicoverpa and Sorghum Head Caterpillar, and appear to have low impact on beneficial insects.
- In laboratory and semi-field trails, Movento™ had nil or a minor impact on the beneficials tested; Belt™ and Coragen™ varied from a moderate to nil impact; and *Trichogramma* was not impacted by any of these three 'soft options'.

### 6.11 New South Wales – Soft Options - Discussion

#### a) 2005-06 Trials - Discussion

In both trials the high and low rates of SCLI-01 and SCLI-02 provided a similar level of helicoverpa control as the industry standard of Success™.

The treatments of SCLI-03 and Avatar™ also provided a similar level of helicoverpa control as Success but were not always significantly better than the untreated plots.

SCLI-01 and SCLI-02 were both effective in controlling helicoverpa when applied to sweet corn during the silking stages. Avatar and SCLI-03 were also efficacious against helicoverpa but the efficacy level was not as high as SCLI-01, SCLI-02 or the industry standard of Success™.

#### b) 2006-07 Trials - Discussion

In both trials the low and high rates of SCOI-01 and SCOI-02 (with or without a wetter) provided a similar level of helicoverpa control as the industry standard of Success™.

There appeared to be a rate response for SCLI-01 even though there were no significant differences between the high and low rate for any measurement in both trials.

There appeared to be only a very slight improvement in efficacy when applying SCLI-02 with the addition of Agral™ as a wetter.

The treatment of Avatar™ provided a similar level of helicoverpa control as Success™, SCOI-01 and SCOI-02 but was no better than the untreated plots.

SCOI-01 and SCOI-02 were both effective in controlling helicoverpa when applied to sweet corn during the silking stages. The efficacy of SCOI-01 and SCOI-02 was similar to the industry standard of Success™ and better than the untreated plots. Avatar™ also had similar efficacy results to Success™ but the results were no better than the untreated plots.

### c) Additional 2007 non-replicated Trial - Discussion

## Helicoverpa control:

Results were very similar for the plots treated with SCLI-02 and SCLI-01 with 77% sustaining no damage from helicoverpa larvae. For both the SCLI-02 and SCLI-01 treatments only 17% of the cobs sustained slight tip damage leaving only 7% of the cobs with significant damage. For the alpha cypermethrin and control plots, 27% and 42% respectively of cobs remained free of damage and 45% and 23% respectively sustained slight tip damage. Thirty percent of the cobs from both the alpha cypermethrin and control plots sustained significant damage from heliothis larvae.

## Secondary Pests:

It is difficult to come to conclusions from these results due to the variability evident between the plots in the pre-treatment period and the fluctuating numbers of thrips throughout the trial. As a whole the results of chemical effects upon thrips are inconclusive and it is difficult to draw any conclusions from this data.

Results from the crop monitoring indicate that SCLI-02 had little or no affect as compared to the control treatment, upon the aphid population.

Results for SCLI-01 are more difficult to interpret with the aphid population reaching 5 per plant in Wk2 as compared to only one to every ten plants and zero in the SCLI-02 and the control plots respectively. Numbers then dropped down to zero Wk3. The low aphid numbers in the control and new chemistry plots from Wk3 on could be caused by the beneficial insect populations i.e. ladybird beetles that can keep aphid populations in check. It is known that alpha cypermethrin is toxic to aphids. The results supported this fact by revealing very low numbers for the first 2 weeks following the first spray application. At Wk3 the alpha cypermethrin plot showed an increase in the aphid population to over 10 aphids per plant. It is likely that alpha cypermethrin was toxic to aphid predators and parasitoids thereby causing a pest resurgence once residue levels had been reduced. Aphid predators can be effective at keeping the aphid population in check as was observed in the other three treatment blocks. The overhead irrigation may have washed off the alpha cypermethrin residue allowing recolonisation within two weeks of the last application. Relatively large numbers of aphids were found in cobs from the alpha cypermethrin treated plot as compared to the other treatments supporting the observations made from the field monitoring.

## Conclusion:

With no replication, the purpose of this trial was to observe population trends within the different treatment plots. With predominantly low insect numbers throughout the trial and typically highly variable pre-treatment counts interpretations from the results were restricted.

The two new chemicals SCLI-02 and SCLI-01 both demonstrated very good control of heliothis as compared to the control and alpha cypermethrin. Both of the new chemicals also demonstrated very little impact upon ladybird beetles, red and blue beetles, spiders and yellow mirids. Results indicated that SCLI-02 had little or no efficacy upon pirate bugs and that SCLI-01 had slight to moderate efficacy against them. Inconclusive results were obtained as to the spray treatments affects upon lacewings and parasitic wasps (*Trichogramma spp*). The results show that by Wk5 (post harvest), the population numbers in each of the treatments for most of the pests and beneficials (excluding aphids) had come together. This is most likely due to insect migration within and around the trial block. Any insecticide residues were likely to have been washed off the crop from the overhead irrigation by that stage. Therefore all plots were likely to be potential habitats for insect species from neighbouring plots.

The zero or low efficacy of SCLI-02 and SCLI-01 upon ladybird beetles, red and blue beetles spiders and yellow mirids indicates that these two new chemicals may increase the integrated pest management capacity of sweet corn cropping by providing more options against heliothis that are 'soft' towards beneficial populations. More evaluation of these two new chemicals to determine their effect upon parasitic wasp populations would be of benefit.

The toxicity of alpha cypermethrin upon the secondary pests and beneficial insects was usually very high. Exceptions to this were observed with the thrips, lacewing and pirate bug populations where survival rates were either quite high (as for thrips) or just inconsistent in the monitoring results from Wk1 and Wk2. Field scouting dates for Wk 1 and Wk2 were sprayed five and six days respectively before the plots were monitored. Therefore results from week one and two are likely to indicate more accurately what impact the different treatments had upon the insect populations than those from Wks 3 and 5.

### d) 2007-08 Trials - Discussion

Two trials were conducted during the 2007/08 season at the Yanco Agricultural Institute, NSW, to assess the efficacy of different spray programmes that were based either on new generation, narrow spectrum chemicals or older broad spectrum chemicals for controlling helicoverpa (*Helicoverpa armigera*). Two spray programs (treatments) evaluated the use of SCLI-02 when first applied at silking.

*Helicoverpa armigera* (helicoverpa) is the major insect pest of sweet corn in the Riverina with the range of sucking pests (including aphids and thrips) only considered as a minor secondary problem. The sweet corn industry in the Riverina has not adopted 'soft options' for the management of helicoverpa. Two to three chemical applications of broad spectrum insecticides are commonly used as the primary management tool which generally starts at early tasselling. Two trials were conducted during the 2007/08 season to assess the efficacy of different spray programmes that were based either on new generation, narrow spectrum chemicals or older broad spectrum chemicals for controlling helicoverpa. Two spray programs (treatments) evaluated the use of SCLI-02 when first applied at silking. Both of these programs involved rotating with Success™ and one also included an earlier application of Avatar™ at tasselling. The effectiveness of these two spraying programmes was compared to the typical spray program followed by local sweet corn growers who use broad spectrum chemicals to produce corn for the processing market. In addition, the grower's spray program was evaluated at both high and low water rates. The low water rate was applied to simulate a standard "over the top" boom spray application. The high water rate was applied to simulate a boom fitted with droppers to help improve spray coverage to the target area. The spray treatments were also compared with a nil spray program where no spray treatments were applied.

Results showed the two treatments which used SCLI-02 at silking, and then rotated with Success™ gave significantly greater helicoverpa control in sweet corn compared to any other treatment. The addition of Avatar™ at tasselling, when using a SCLI-02/Success™ rotation, gave no improvement in helicoverpa control.

Results also showed that using broad spectrum insecticides to control helicoverpa in sweet corn and rotating with Success™ gave significantly greater helicoverpa control compared to leaving the crop unsprayed. Results also demonstrated that when using broad spectrum chemicals, higher water rates applied by a boom fitted with droppers gave significantly better results than applying the insecticides at lower water rates with no droppers fitted.

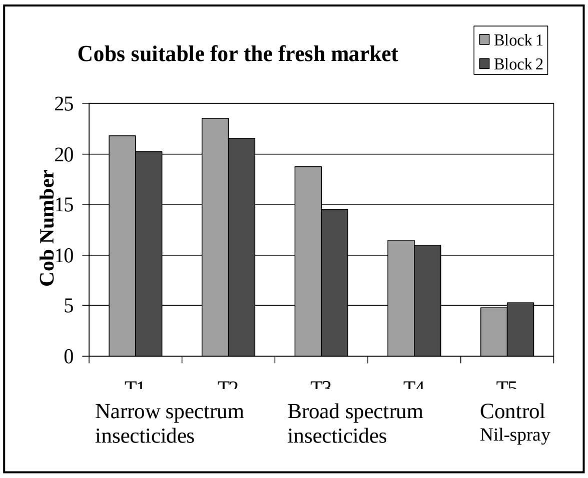
Treatment T5 (control) had significantly higher numbers of "other beetles" than all the 4 spray treatments. Treatments T1 and T2 (using narrow spectrum chemicals) had significantly higher numbers of “other beetles” than treatments T3 and T4 (using broad spectrum chemicals). The insects recorded as “other beetles” included flower, pollen and rove beetles. No distinction was made between these three beetles at the time of scouting (numbers were recorded collectively and it was impossible to separate them later). It was generally observed that flower beetles were the most abundant beetle in the trials, with pollen beetles seen in low numbers and rove beetles rarely observed. Even though the flower beetle was observed and recorded with “other beetles”, it is not considered a beneficial insect in sweet corn.

There was no statistical difference in numbers of ladybird beetles, lacewings, predatory bugs or spiders between any of the treatments. A non-significant trend was observed for lacewings and predatory bugs with higher numbers observed in treatments T1, T2 and T5 than those observed in the treatments T3 and T4 that relied on broad spectrum sprays.

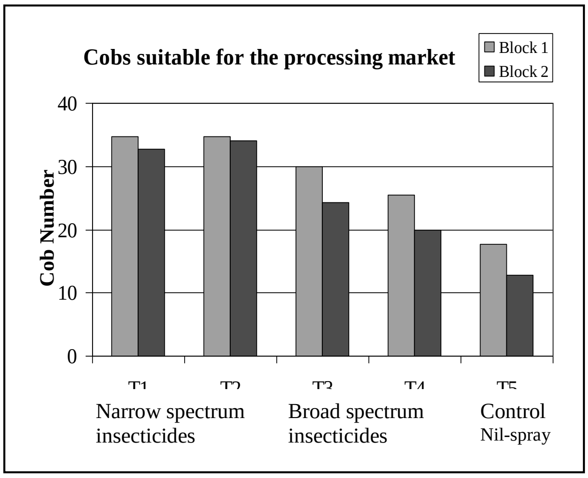
## Conclusion

The spray programs of treatments T1 and T2, which applied SCLI-02 at silking and then rotated with Success, gave significantly greater helicoverpa control in sweet corn than any other treatment. Graphs 29 and 30 below illustrate the greater helicoverpa control, with higher cob yields for fresh and processing markets achieved from treatments T1 and T2 in both trials.

Graph 29: Cob yield for the fresh market




Graph 30: Cob yield for the processing market




The addition of Avatar™ at tasselling, when using a SCLI-02/Success™ rotation gave no improvement in helicoverpa control.

The spray programs of T3 and T4 which applied a rotation of Lannate™ and Dominex™ with Success™ gave significantly greater helicoverpa control in sweet corn compared to a nil spray program. The spray program of Lannate™ and Dominex™, in rotation with Success™, was affected by water rate and application method. When applying this rotation, the helicoverpa control is significantly improved at higher water rates and the use of droppers fitted to the boom.

There were only a low levels of beneficial arthropods observed and recorded in both trials. The range of beneficial arthropods recorded in the trials did not demonstrate adequate control of helicoverpa in the unsprayed plots.

## 6.12 North Queensland – Soft Options - Discussion

Four field trials were established during 2006 and 2007 cropping seasons in Bowen, to evaluate a number of narrow spectrum insecticides and miticides against heliothis, aphids and mites.

SCLI-01 and SCLI-02 applied at the early silking stage consistently performed well in all four trials and provided higher marketable yield than other treatments. SCLI-01 is expected to be registered in sweet corn and other vegetable crops in 2009. Avatar™ provided only a moderate level of heliothis control, while SCLI-03 did not perform very well. SCLI-01 and SCLI-02, at the label rate did not show any adverse effects on predatory ladybirds, *Stethorus* beetle and the aphid parasitoid, *Aphelinus sp*.

Mite-01, an insect growth regulator, suppressed two-spotted and red spider mite populations within 3 weeks of initial application, and is a potential candidate as a 'soft option' for mite control in sweet corn.

SCSI-01 consistently performed well against corn aphids, and also showed some effects on two-spotted mites. High aphid parasitism (up to 72%) was recorded in the SCSI-01 plots, indicating that the product had minimal impact on the *Aphelinus* parasitoid.

### a) Heliothis management - Discussion

SCLI-02 and SCLI-01 were included in Trial 3 in 2007 to confirm their effectiveness against heliothis. Both products performed well and effectively reduced cob damage. SCLI-02 and SCLI-01 plots had the highest number of cobs free of damage (93 to 97%) compared to the untreated control (68%).

In Trial 4, SCLI-02 and SCLI-01 were combined with Success™ (industry standard) to evaluate their effectiveness against heliothis. Pre-treatment egg and larval densities ranged from 1.1 to 3.2 per 10 cobs (Fig 2). All three treatments performed well, and had 83 to 86% cobs free of damage. No significant differences were found between the three treatments.

### b) Aphid management - Discussion

In Trial 2, aphid numbers were very low (0 to 8%) during the flowering and silking periods (Sep / Oct), therefore, aphid products were not evaluated in this trial.

In Trial 3 (2007), aphid numbers were very high at silking (July/ Aug). Three insecticides (SCSI-01, Chess™ and Primor™) were evaluated against aphids. At harvest (28 DAT), SCSI-01 had significantly less aphid infestations than the untreated control (Table 14).

Although Primor™ and Chess™ treatments significantly reduced aphid numbers compared with the control plots, they all resulted in higher cob contamination than SCSI-01. Chess™ did not perform well in controlling corn aphids during the high pest pressure period. Primor™ was moderately effective. SCSI-01 had a significantly higher proportion of marketable cobs (68%) than all other treatments (Fig 5).

### c) Mite management - Discussion

In Trial 2, mite numbers peaked in the crop one week before silking, therefore treatments were applied at the early silking stage.

Mite-01 and SCSI-01 performed well against mites. At the post-treatment count (24 DAT), leaves collected from Mite-01 plots had significantly lower numbers of mites than that in untreated control (Fig 7).

At the harvest (35 DAT), SCSI-01 and Mite-01 had a higher proportion of cobs free of mite infestation (35 and 28%) compared with the untreated control (0.0%) (Table 15), and they had significantly lower unmarketable cobs (28.3 and 16.7%) than all other treatments (Fig 8). Other insecticides (SCLI-01, SCLI-02, and Avatar™) were ineffective in controlling mites in the cobs.

**Summary**

The data demonstrates that SCLI-01 and SCLI-02 have potential for heliothis management in sweet corn, particularly in crops where predator and parasitoid activity is high.

SCLI-01 and SCLI-02 provided adequate control against heliothis. The level of control was consistent in all four trials where the products were exposed to various heliothis pressure during 2006 and 2007 seasons. SCLI-02 performed well and demonstrated its robustness, even at half the label rate.

In addition SCLI-01 and SCLI-02 are generally more selective for Lepidopteran pests and result in less disruption to natural enemies. In these trials it was found that both products did not cause a significant reduction in aphid parasitoid (*Aphelinus sp*.) and ladybird beetles (*Stethorus sp*.) populations.

In North Queensland, corn aphid activity commences in May and increases to the highest numbers during July/August, and then declines in September. Corn aphid pressure is generally low during the October to November period. This shows that the aphids are a potential seasonal pest of sweet corn in the dry tropics region.

The potential of aphids and mites to contribute to marketable yield loss has been quantified in this study. Aphids and mites cause a greater threat, as they contaminate and downgrade the harvested cobs. This is mainly an issue for fresh market production. Currently no specific insecticides are registered in sweet corn to control aphids and mites. The broad spectrum insecticides such as dimethoate and alpha-cypermethrin are the only option available for aphid control and these products are highly disruptive to IPM in sweet corn.

SCSI-01 provided a high level of aphid control with one application at early silk stage. However two applications may be required to achieve a high proportion of marketable cobs. The other two aphicides trialed, Chess™ and Pirimor™ did not provide sufficient control of corn aphids.

SCSI-01 has a greater potential to control aphid and to fit well into a sweet corn IPM program. The trials showed that SCSI-01 did not have any adverse affects on aphid parasitoids and ladybird beetles.

The effects of these new ‘soft option’ insecticides on beneficial arthropods has not been fully studied in these trials. It would be difficult to assess their full impact in these small plot trials because beneficials are highly mobile and move between treated and untreated plots. However the data shows there was a trend in increasing numbers of ladybird and aphid parasitoids in the SCLI-01, SCLI-02 and SCSI-01 plots.

A high level of aphid parasitism recorded in all treated trial plots (Trial 2 in 2006) were due to natural colonization of *Aphelinus sp*. This species has not been reported before in the dry tropics region, and appears to be a potential naturally occurring beneficial for sweet corn IPM.

Natural enemies continue to have an important regulatory impact on heliothis, aphids and mites. While several species of predators and parasitoids are naturally occurring in the dry tropics region, their numbers are often small because of intensive agricultural practices. These natural enemies unfortunately develop more slowly and are more susceptible to broad-spectrum insecticides, thus limiting their effectiveness under these conditions. It is expected that these natural enemies are more likely to be effective when `softer' insecticides are used.

The registration of these products in sweet corn, in addition to other vegetables such as tomato, capsicum, cucurbits and brassica would increase the length of seasonal usage and increase resistance selection pressure. Therefore appropriate guidelines for managing resistance in heliothis should be implemented at regional level, when registration of these soft options occurs.

The results of these trials provide useful information for understanding how to effectively use the new insecticides within existing sweet corn IPM program. Effectiveness of these new chemistries can be influenced by spray timing and application. Seasonal pests such aphids and mites have the potential to reproduce very rapidly in the ideal temperatures, so that regular monitoring is essential for timing insecticide applications.

## 6.13 South Queensland – Soft Options - Discussion

Three trials were planted on the Gatton Research Station - 25$^{th}$ January and harvested on the 18$^{th}$ April 2006 using Hi-brix (formally H5); 7$^{th}$ September and harvested on the 4$^{th}$ December 2006 using Golden Sweet; and 6$^{th}$ February 2007 using Hi-Brix; to evaluate a range of insecticides for lepidopteran insects and sap sucking insect control, and to monitor the effects of insecticides on naturally occurring beneficials.

### Conclusions

- SCSI-03b was effective against sucking insects (thrips and aphids), particularly early in the trial; efficacy against thrips was lost later in the crop life but appeared to still be working against aphids at harvest. The other 2 neo-nicotinoids Actara ™ and Confidor Guard ™ also gave some control of thrips and aphids early in the crop life and mixed results for aphids at harvest.
- SCSI-01 (formally SCSI-01) worked well against aphids at harvest.
- There is potentially now sap sucking insecticides for sweet corn.
- These new sap sucking insecticides do appear to have some effect on the beneficial insect predators and so care should be used.
- They do not appear to affect trichogramma populations.
- Both SCLI-01 and SCLI-02 worked exceptionally well against helicoverpa and sorghum head caterpillars in sweet corn where they could have a place in their management in the future.
- These 2 new lepidopteran insecticides appear to have low impact on beneficial insects with more work required in this area.
- Avatar and SCLI-03 gave poor control of the lepidopteran pests and so should not be pursued any further.
- SCSI-02 foliar appeared to have some effects against Lepidoptera, although results were inconclusive and gave mixed results on the sap sucking insect pests.

### a) Trial 1 – Discussion

At harvest all insecticidal treatments were better at controlling helicoverpa numbers than the unsprayed control. The control treatment had over 2 larvae present in 10 cobs assessed while all treatments had no more that one larva in 20 cobs with the majority less than this, Avatar™ being the poorer performer of the insecticide treatments with one in 20 cobs. There was no significant difference between treatments for yellow peach moth control. This is most likely due to the relatively small numbers of larvae found in the crop and between treatments. However, SCLI-02 and the high rate of SCLI-01 had less larvae present in the cob than the control treatment. The SCLI-03 treatment had more larvae present that all other treatments including the unsprayed control. The presence of sorghum head caterpillars, was quite variable between treatments with more than 10 larvae found in 10 cobs for the SCLI-03 treatment to a low of less than 2 larvae in 10 cobs for the high rate of SCLI-02 treatment. The high rate of SCLI-02 was the only treatment that was significantly better than the unsprayed control treatment at reducing caterpillar numbers. With the exception of SCLI-03, all other insecticidal treatments did show a reduction in caterpillar activity compared to the control treatment although these were not significant.

The damage to the cobs was significantly less in all treatments except the SCLI-03 treatments compared to the unsprayed control. The control plots had up to 25% damage to the cobs where as the best treatments were SCLI-02 and the high rate of SCLI-01 with no damage found on the tips or sides of the cobs.

SCSI-03a would appear to be a good product for the control of thrips early in the crops life, even up to 34 DAP with thrips numbers being much less than what was found in the unsprayed control plants. Assessment of thrips numbers on the cobs at harvest is the next step as this was not undertaken as part of this trial but will be a part of a future trial with this product. The residual of this product appeared to be good particularly against aphids at harvest with very few aphids found on the plants within this treatment compared to large numbers on untreated plants. Its effect on leafhoppers or jassids still needs to be investigated. SCSI-01 also showed benefit against aphids in particular, with very few aphids found on the plants at harvest. Its effect against thrips is not yet clear with more work being required.

The 2 new lepidopteran insecticides SCLI-01 and SCLI-02 gave good control of helicoverpa and the secondary pest sorghum head caterpillar but only a visible difference to yellow peach moth numbers. These insecticides also significantly reduced the amount of damage to cobs at harvest as a direct result of controlling helicoverpa and the secondary lepidopteran pests which are an issue during autumn plantings in Southeast Queensland. The effectiveness of SCLI-03 against the lepidopteran insect pests was variable with a positive result against helicoverpa but not the other pests. SCSI-01 did appear to have some effect against the lepidopteran pests even though it is recommended as a sap sucking insecticides and so needs more work carried out on it to determine its full potential in this area. Avatar™ also had mixed results in controlling these pests with significantly less damage to the cobs but not always significantly less caterpillar pests.

All the insecticidal treatments did not appear to have any detrimental affect on the beneficial insect populations with similar numbers of the more commonly found beneficial insects being present throughout all the treatments during the silking period especially the egg parasitoid trichogramma.

**b) Trial 2 – Discussion**

Thrips can cause damage to the emerging leaves of sweet corn by rasping and sucking the leaf juices leaving distinct streaking on the leaves which could in the long run affect the yield or maturity time of sweet corn. The thrips causing the damage to the plants if *Frankliniella williamsi* or maize thrips and can be found attacking this crop from the moment it emerges from the ground until the cob is picked up to 100 days later. The two neo-nicotinoid products tested showed a great deal of success at reducing thrips numbers in the seedlings and young plants even up to 46 days after planting. Although this product was applied in a furrow at planting it could be possible for these products to be applied as seed dressings and should be investigated in any future work. Thrips counts on the cobs at harvest were not recorded properly and so it is unclear as to the long term effect of these products on thrips in terms of managing this pest through to harvest. The rapid increase in numbers of thrips on the plants after 33 days after planting would most likely be due to the rapid growth of the plants resulting in the dilution of the chemical within the plants giving the thrips lower doses which could result in taking longer to kill off the thrips.

The newer insecticides used to control the helicoverpa also show promise. Both SCLI-01 and SCLI-02 worked well against helicoverpa, reducing damage levels to cobs down to three to four percent compared to 16% for doing nothing. The higher than expected result from the high rate of SCLI-02 was still not significantly different from the low rate of this same product and so does need additional work on it to fine tune either the timing of the product or the number of applications required to manage this sweet corn pest. SCLI-03 and Avatar™ do not seem to have any place in the sweet corn pest management options due to their poor performance both with respect to damaged cobs and the presence of the larvae found in the cobs.

The effect of these insecticide products on the beneficial insect population is vitally important in developing an IPM system, as IPM is about using all available tools to manage insect pests. Any insecticides that also affect the beneficial insect population could disrupt the balance that growers have been developing over the years which has been to encourage beneficial insects to aid their cause in the fight against the range of insect pests, in particular helicoverpa, that are known to attack sweet corn.

At first glance there is no consistent significant differences between treatments when assessing their impact on the range of beneficial insects. There is some significant differences between treatments when looking at predatory bugs on the 24th November but this did not follow through to the next assessment. What was evident from Figure 15 and the YST catches is that the early silking or pre-spray assessment showed the largest numbers of beneficial insects in all treatments. Once the insecticides were applied these numbers dramatically declined even in the unsprayed control plots. Of particular concern is the trichogramma numbers which dropped by more than half across the entire trial area. They did however remain active throughout the rest of the trial and could still be found even after the insecticides had been applied but they never recovered to the same levels as at the start of silking. The predatory bugs also declined significantly after the first sprays but they did recover to levels close to the pre-spray records.

In contrast, the direct field monitoring results showed the predatory bugs unaffected by the various insecticides although the insecticide treated plots were at one stage significantly lower than the untreated control plots even though they had increased in numbers from the pre-spray assessment. The predatory beetles and spiders also showed an increase in numbers over time with significant differences only appearing between treatments closer to harvest. There did however appear to be more predatory beetles in the SCLI-01 plots in the form of the small brown Anthicid beetles that are considered predatory on small insects and eggs. These were observed predominantly in the silks when monitoring and not on the YST.

Both direct field monitoring and the YST need to be compared together as what can not be found with field monitoring may then be caught on the YST as with the trichogramma and visa versa not all insects are attracted to the YST to the same degree and may be more readily found by directly observing them in the crop.

**c) Trial 3 – Discussion**

SCSI-03b was the most effective insecticide for the control of thrips, the main pest from sowing to silking. This insecticide resulted in significantly fewer thrips compared to the control up to 34 DAS, compared with suppression up to 27 DAS for Confidor Guard™. Actara™ and SCSI-02 also provided some level of control during this period. However, from silking to harvest, Confidor Guard™ was the only soil applied treatment to provide any control of thrips. SCSI-02 foliar and dimethoate were the most effective thrips control treatments during the latter part of the trial. By the harvest assessment, dimethoate was the only treatment to still provide a level of control of thrips.

Aphids were also present throughout the trial period. From sowing to silking, SCSI-03b and Actara™ provided some control (significant at 20 DAS). SCSI-03b was also effective later in the trial (at 71 DAS), as were Confidor Guard™, SCSI-01 and dimethoate. At harvest aphid distribution was too patchy to determine any meaningful treatment effect.

The only other pest for which any statistically significant effect of treatment could be determined was jassids, with dimethoate providing effective control at 79 DAS.

Effects of treatments against lepidopteran pests were inconclusive, as numbers were generally too low to allow meaningful comparison of treatments. There was no significant effect of treatment on numbers of helicoverpa eggs or larvae from silking to harvest, but at harvest no cob damage or caterpillars of any species were found in the SCSI-02 foliar treatment.

For all other pests either numbers were too low to allow analysis or there was no significant effect of treatment.

Dimethoate had an adverse effect on the majority of beneficials during the latter part of the trial (silking to harvest). Some of the other insecticides also resulted in significantly lower beneficials numbers on occasion, although these effects were not generally found to be consistent over time or between species. None of the insecticides had any effect on helicoverpa egg parasitism, nor on the number of trichogramma caught on sticky traps. The constant presence of trichogramma throughout the latter part of this trial could have contributed to the low levels of Lepidopteran pests in all treatments regardless of their effectiveness on this pest group.

**Summary**

A number of narrow spectrum pesticides (coded to maintain confidentiality for the duration of the project) have been made available to the project team through three chemical companies [Bayer/Dupont/Sumitomo]. This activity has assessed their IPM fit, and provided some efficacy data to enable these companies to proceed where appropriate with registration in sweet corn in Australia.

SCSI-03 has provided very good control of thrips in the early crop stages, and has extended residual effects to be able to manage aphids up to harvest. SCSI-01 also gave good control of aphids up to harvest. SCLI-01 and SCLI-02 were very good at managing helicoverpa and sorghum head caterpillars by providing clean undamaged cobs free from caterpillars.

Mite-01 suppressed the 2-spotted and red spider mite populations within 3 weeks of application, and showed minimal impact on ladybird beetle beneficials.

All treatments have shown minimal detrimental affects on the beneficial insect populations, although additional work needs to be undertaken, specifically with respect to the effects on trichogramma to determine the true effect of these soft options on the beneficial wasp populations.

## 6.20 Monitoring Pests and Beneficial Organisms - Discussion.

**A wide range of insect pest species have been observed in sweet corn crops grown for the fresh market and processing industry throughout the Australian growing regions.** The most commonly seen beneficial insects included predatory thrips, red and blue beetles, pirate bugs, spiders, ladybird beetles and evidence of parasitic wasps.

Helicoverpa (*Helicoverpa armigera*) is generally observed in larger numbers during the final growth stages of the crop (tasselling and silking stages) than in the earlier growth stages (seedling and vegetative stages). The numbers of Helicoverpa larvae in most crops are high enough to cause a marketable yield loss if not managed correctly.

Other secondary pests including aphids, mites and thrips occur in most regions but not always in large enough numbers to cause an economic yield reduction. They are often seasonal pests.

Apart from understanding the key pests and natural enemies in sweet corn and the way they interact with each other and the crop, other non-chemical control methods that seek to suppress pest populations can play an important role in successful biological control. This is partly because many natural enemies are more likely to have an impact when initial pest populations are low.

The key is to know what pests and beneficials are in the crop (monitoring), what they are capable of, and make decisions accordingly.

There are many beneficial insects and spiders that can play an important role in minimising pest numbers and damage to sweet corn. For them to be effective, selective insecticides that have minimal impact on beneficial insects, should be used where possible, and regular monitoring of changes in populations of pests and beneficial insects and spiders is critical.

Without some direct monitoring, natural enemies can remain unseen and under-appreciated. Knowing what is there enables appropriate insecticide selection around preserving the key beneficial groups present and active in the crop at that time.

Attempting to rely on biological control will not be practical for every pest. Helicoverpa, aphids and mites all have a diverse and well adapted suite of natural enemies that attack them and that are capable of reducing pest numbers in the crop. But there are other pests like green vegetable bug, leafhoppers and many soil pests that, once they are detected at potentially damaging levels, are unlikely to be brought under control by natural enemies.

Not all natural enemies present in crop are equally beneficial. Some, like *Trichogramma pretiosum* - a key natural enemy of Helicoverpa in sweet corn – are vital to the success of an IPM approach, and efforts to base insecticide selection around its preservation are well justified. Other natural enemies, while important, kill their prey or host too late in the pest's lifecycle to prevent it from causing crop damage.

### 6.21 New South Wales - Monitoring Pests and Beneficial Organisms - Discussion

#### a) Additional 2007 non-replicated Trial - Discussion

#### Parasitism:

For all of the major beneficial insects that were caught on sticky traps, including ladybird beetles and pirate bugs, the data recorded is difficult to interpret because numbers caught in the treated plots often exceeded those found in the control plot. From the sticky trap data for thrips numbers, it is not possible to draw any conclusions as population numbers do not reveal trends and are rather random. This could be explained by the fact that thrips are winged and highly mobile within and between crops. It may be that thrips caught on these sticky traps were merely incidentals passing through the sweet corn trial from other food sources. Therefore results from the sticky trap observations were inconclusive for the purpose of this trial. For the list of the specimens found on the sticky traps in this trial please see appendix 1.

## Conclusion:

With no replication, the purpose of this trial was to observe population trends within the different treatment plots. With predominantly low insect numbers throughout the trial and typically highly variable pre-treatment counts interpretations from the results were restricted.

The two new chemicals SCLI-02 and SCLI-01 both demonstrated very good control of heliothis as compared to the control and alpha cypermethrin. Both of the new chemicals also demonstrated very little impact upon ladybird beetles, red and blue beetles, spiders and yellow mirids. Results indicated that SCLI-02 had little or no efficacy upon pirate bugs and that SCLI-01 had slight to moderate efficacy against them. Inconclusive results were obtained as to the spray treatments affects upon lacewings and parasitic wasps (*Trichogramma spp*). The results show that by Wk5 (post harvest), the population numbers in each of the treatments for most of the pests and beneficials (excluding aphids) had come together. This is most likely due to insect migration within and around the trial block. Any insecticide residues were likely to have been washed off the crop from the overhead irrigation by that stage. Therefore all plots were likely to be potential habitats for insect species from neighbouring plots.

The zero or low efficacy of SCLI-02 and SCLI-01 upon ladybird beetles, red and blue beetles spiders and yellow mirids indicates that these two new chemicals may increase the integrated pest management capacity of sweet corn cropping by providing more options against heliothis that are ‘soft’ towards beneficial populations. More evaluation of these two new chemicals to determine their effect upon parasitic wasp populations would be of benefit.

The toxicity of alpha cypermethrin upon the secondary pests and beneficial insects was usually very high. Exceptions to this were observed with the thrips, lacewing and pirate bug populations where survival rates were either quite high (as for thrips) or just inconsistent in the monitoring results from Wk1 and Wk2. Field scouting dates for Wk 1 and Wk2 were sprayed five and six days respectively before the plots were monitored. Therefore results from week one and two are likely to indicate more accurately what impact the different treatments had upon the insect populations than those from Wks 3 and 5.

### b) 2007-08 Trials - Discussion

Two trials were conducted during the 2007/08 season at the Yanco Agricultural Institute, NSW, to assess the efficacy of different spray programmes that were based either on new generation, narrow spectrum chemicals or older broad spectrum chemicals for controlling helicoverpa (*Helicoverpa armigera*). Two spray programs (treatments) evaluated the use of SCLI-02 when first applied at silking.

Flower beetles were the most abundant beetle in the trials, with pollen beetles seen in low numbers and rove beetles rarely observed. Even though the flower beetle was observed and recorded with “other beetles”, it is not considered a beneficial insect in sweet corn.

There were low levels of a fairly large range beneficial arthropods observed and recorded in both trials. These did not demonstrate adequate control of helicoverpa in the unsprayed plots.

There was no statistical difference in numbers of ladybird beetles, lacewings, predatory bugs or spiders between any of the treatments.

A non-significant trend was observed for lacewings and predatory bugs with higher numbers observed in narrow spectrum insecticide treatments than those observed in the broad spectrum spray treatments.

## 6.22 Western Australia - Monitoring Pests and Beneficial Organisms - Discussion

From 23 November 2005 to 31 January 2007, monitoring was conducted once per week by the Department of Agriculture and Food WA at Wanneroo, approximately 25 km north of Perth. Additional information was obtained from a commercial IPM company (Manchil IPM) monitoring the same Wanneroo property (2007/08) and another commercial farm at Baldivis (2006/07). At both sites, sweet corn was grown on sandy soils on the Swan Coastal plain and irrigated by overhead irrigation.

The primary pest of sweet corn in Western Australia is helicoverpa. Growers currently use a combination of biological and chemical tactics for its control. This should reduce selection pressure on insecticides, which in turn could delay the development of insecticide resistance. The use of biological and chemical control tactics may also provide simultaneous control of helicoverpa, which may be more effective that either tactic alone. Biological control currently consists of innundative releases of the wasp *Trichogramma pretiosum* at the seedling stage, with one to three releases per crop.

Secondary pests of sweet corn included sorghum head caterpillar *Spodoptera litura*, corn aphid, *Rhopalosiphum maidis,* and two spotted spider mite, *Tetranychus urticae*. These pest species tended to appear later in the season (January-April), and sometimes required chemical control.

In the 2005/06 season, all pests and a range of beneficials were present in the crop throughout the growing season, and at all plant growth stages, except for aphids and two-spotted mite which were more abundant toward the end of the growing season (February-April). Aphids and two-spotted spider mite are late season pests.

Naturally occurring predators included brown and green lacewings (*Micromus* spp.; *Mallada signata* (Schneider)), ladybirds (*Coccinella transversalis* Fabricius; *Hippodamia variegata* (Goeze)), spiders (various families), damsel bugs (*Nabis* spp.) and the Chilean predatory mite, *Phytoseiulus persimilis*, a mite predator of two spotted mite. In April 2008, a species of *Orius* sp. was documented for the first time from sweet corn at Wanneroo.

There appeared to be no correlation between lacewing and ladybird abundance with pest abundance. Damsel bugs were never abundant during our study and occurred only in January-February.

Spiders were found during all months. Spiders were not identified to species, except for the distinctive Christmas spider (*Austracantha minax* (Thorell); family Araneidae). Other spider families collected during the study included other species of Araneidae (weavers), Salticidae (jumping spiders) and Lycosidae (wolf spiders).

In the 2006/07 season, the numbers of beneficials were lower.

At Wanneroo, brown lacewings were present at all times. In November 2007, brown lacewing abundance was very high, but this did not appear to be correlated with pest abundance, which was low for both helicoverpa and aphids. Similarly, in the previous year (November 2006) high numbers of brown lacewings were recorded.

Brown lacewings may be migrating from surrounding pastoral areas as weeds and broad acre crops dry up, and are probably attracted to sweet corn for shelter and the pollen for food.

Insecticide applications included IPM friendly (Gemstar) and broad-spectrum insecticides (Sonic, cypermethrin) to used to manage helicoverpa and sorghum head caterpillar respectively. Insecticide applications appeared to reduce the beneficials population.

trichogramma was obtained from BioResources P/L (Queensland), and releases were made at the vegetative stage and up to 100% parasitism recorded in some blocks at Baldivis. Parasitism rates also appeared to increase over time in some blocks, which may be attributed to populations of trichogramma establishing in sweet corn during the growing season.

### 6.23 North Queensland - Monitoring Pests and Beneficial Organisms - Discussion

Four field trials were established during 2006 and 2007 cropping seasons in Bowen, to evaluate range of narrow spectrum insecticides and miticides against helicoverpa, aphids and mites, and to assess their effects on naturally occurring arthropods.

**Beneficial arthropods**: Beneficials found in sweet corn during these trials were ladybird beetles, lacewings, hoverfly brown smudge bugs and spiders. Ladybirds (larvae and adults) were more abundant in the crops. Three species, *Coccinella transversalis*, *Coelophora inaequalis and Stethorus sp*, were recoded. Ladybird numbers were similar in all treatments plots, and no significant differences were recoded between treated and untreated plots. SCLI-02 and SCLI-01 application did not cause any noticeable adverse effect on ladybird numbers in the plots.

SCSI-01 performed well and effectively controlled aphid infestation in this trial.

Aphid parasitism was recoded in all treatments, including moderate level of parasitism in Primor™ plots. The parasitism level ranged between 47 to 76 %. High level of parasitism were recorded in SCSI-01 plots, indicating that the product is less harmful for the parasitoid species. *Aphelinus* sp was the most abundant species found in the trial crops. A small proportion of another parasitoid, *Lysephlebus testaceipes* was also recorded.

Mite-eating ladybird beetle (*Stethorus sp*) was the major predatory insects recorded in the leaf and cob samples. *Stethorus* beetle and larvae numbers did not significantly vary between treated and untreated plots, except Avatar™. SCLI-02 and SCLI-01 applications did not cause any noticeable adverse effect on ladybird numbers in the plots. Stethorus is a small (5 mm) black beetle and lays eggs in mite colonies. The larvae, which feed on mite eggs, are grey in colour.

The data indicate that SCLI-01 and SCLI-02 have potential for helicoverpa management in sweet corn, particularly in crops where predator and parasitoid activity is high.

SCLI-01 and SCLI-02 provided adequate control against helicoverpa. The level of control was consistent in all four trials where the products were exposed to various helicoverpa pressure during 2006 and 2007 seasons. SCLI-02 performed well and demonstrated its robustness, even at half of label rate.

In addition SCLI-01 and SCLI-02 are generally more selective to Lepidopteron pests and result in less disruptive for natural enemies. Both products did not cause significant reduction on aphid parasitoid (*Aphelinus* sp) and ladybird beetles (*Stethorus* sp.) populations.

In North Queensland, corn aphid activity commences in May and increases to higher numbers during July/ August and then declines in September. Corn aphid pressure was low during October to November period, demonstrating that the aphids are a potential seasonal pest in sweet corn in the dry tropics region.

The potential of aphids and mites to contribute to marketable yield lost has been quantified in this study. Aphids and mites cause greater threats as they contaminate and downgrade the harvested cobs. This is mainly an issue for fresh market producers. Currently no specific insecticides are registered in sweet corn to control aphids and mites. The broad spectrum insecticides such as dimethoate and alpha-cypermethrin are the only options available for aphid control and these products are highly disruptive to IPM in sweet corn.

SCSI-01 provided a high level of aphid control with one application at early silk stage. However two applications maybe required to achieve a high proportion of ‘fresh market’ cobs. The aphicides, Chess™ and Primor™ did not provide sufficient control for the corn aphids in this trial.

SCSI-01 has a greater potential for aphid control and will fit into a sweet corn IPM program. In this trial SCSI-01 did not show any adverse affects on aphid parasitoids and ladybird beetles.

The effect of these new generation insecticides on beneficial insect has not been fully studied in these trials. It would be difficult to assess their full impact in these small plot trials because beneficials are highly mobile and move between treated and untreated plots. However there was a trend in increasing numbers of ladybird and aphid parasitoids in the SCLI-01, SCLI-02 and SCSI-01 plots.

The high level of aphid parasitism recorded in all treated trial plots (Trial 2 in 2006) were due to natural colonization for *Aphelinus* sp. This species has not been reported before in the dry tropics region and appear to be a potential resource for sweet corn IPM.

Natural enemies continue to have an important regulatory impact on helicoverpa, aphids and mites. Several species of predators and parasitoids are naturally occurring in the dry tropics area, but their numbers are often small because of intensive agricultural practices. These natural enemies unfortunately develop more slowly and are more susceptible to broad-spectrum insecticides, thus limiting their effectiveness. It is expected that natural enemies are likely to be more effective when the `softer' insecticides are used.

The registration of these products in sweet corn, in addition to other vegetables such as tomato, capsicum, cucurbits and brassicas would increase the production for season-long usage that would increase resistance selection pressure. Therefore appropriate guidelines for managing resistance in helicoverpa should be implemented at a regional level.

The results of these trials provide useful information for understanding how to effectively use the new insecticides within existing sweet corn IPM program. The effectiveness of these new chemistries can be influenced by spray timing and application. Seasonal pests such aphids and mites, have the potential to reproduce very quickly under ideal temperatures, so that regular monitoring is essential for timing the insecticide application.

## 6.24 South Queensland - Monitoring Pests and Beneficial Organisms - Discussion

Three trials were planted on the Gatton Research Station - 25$^{th}$ January and harvested on the 18$^{th}$ April 2006 using Hi-brix (formally H5); 7$^{th}$ September and harvested on the 4$^{th}$ December 2006 using Golden Sweet; and 6$^{th}$ February 2007 using Hi-Brix; to evaluate a range of insecticides for lepidopteran insects and sap sucking insect control, and to monitor the effects of insecticides on naturally occurring beneficials.

### a) Trial 1 – Discussion

All the insecticidal treatments did not appear to have any detrimental affect on the beneficial insect populations with similar numbers of the more commonly found beneficial insects being present throughout all the treatments during the silking period especially the egg parasitoid trichogramma.

### b) Trial 2 – Discussion

The effect of these insecticide products on the beneficial insect population is vitally important in developing an IPM system, as IPM is about using all available tools to manage insect pests. Any insecticides that also affect the beneficial insect population could disrupt the balance that growers have been developing over the years which has been to encourage beneficial insects to aid their cause in the fight against the range of insect pests, in particular helicoverpa, that are known to attack sweet corn.

At first glance there is no consistent significant differences between treatments when assessing their impact on the range of beneficial insects. There is some significant differences between treatments when looking at predatory bugs on the 24$^{th}$ November but this did not follow through to the next assessment. What was evident from Figure 15 and the YST catches is that the early silking or pre-spray assessment showed the largest numbers of beneficial insects in all treatments. Once the insecticides were applied these numbers dramatically declined even in the unsprayed control plots. Of particular concern is the trichogramma numbers which dropped by more than half across the entire trial area. They did however remain active throughout the rest of the trial and could still be found even after the insecticides had been applied but they never recovered to the same levels as at the start of silking. The predatory bugs also declined significantly after the first sprays but they did recover to levels close to the pre-spray records.

In contrast, the direct field monitoring results in Figure 14 showed the predatory bugs unaffected by the various insecticides although the insecticide treated plots were at one stage significantly lower than the untreated control plots even though they had increased in numbers from the pre-spray assessment. The predatory beetles and spiders also showed an increase in numbers over time with significant differences only appearing between treatments closer to harvest. There did however appear to be more predatory beetles in the SCLI-01 plots in the form of the small brown Anthicid beetles that are considered predatory on small insects and eggs. These were observed predominantly in the silks when monitoring and not on the YST.

Both direct field monitoring and the YST need to be compared together as what can not be found with field monitoring may then be caught on the YST as with the trichogramma and visa versa not all insects are attracted to the YST to the same degree and may be more readily found by directly observing them in the crop.

### c) Trial 3 – Discussion

Dimethoate had an adverse effect on the majority of beneficials during the latter part of the trial (silking to harvest). Some of the other insecticides also resulted in significantly lower beneficials numbers on occasion, although these effects were not generally found to be consistent over time or between species. None of the insecticides had any effect on helicoverpa egg parasitism, nor on the number of trichogramma caught on sticky traps. The constant presence of trichogramma throughout the latter part of this trial could have contributed to the low levels of Lepidopteran pests in all treatments regardless of their effectiveness this pest group.

## 6.30 Disease Management - Discussion.

A survey of growers in the major production districts through Queensland, New South Wales, Victoria, Western Australia and Tasmania was conducted principally to determine the range of sweet corn diseases encountered and their severity.

**The survey data** indicates that, while the effects of diseases on production were reported as high as 30%-50% in one region, none of the diseases currently have a major impact on the overall Australian sweet corn production. **A key to this is the range of management practices available to growers to manage these diseases. Integral to these practices is the widespread adoption of Integrated Pest Management (IPM).**

While a significant number of diseases are present throughout the industry in Australia, few of the diseases mentioned by growers in the survey occur extensively throughout the geographic spread of the industry. The best known and most widely distributed of the diseases mentioned were *Turcicum leaf blight* and *Common rust* and the general area of soil-borne diseases/establishment problems (which in many cases may be due to soil insects as such problems are difficult to diagnose). These two leaf diseases have occurred in crops in at least some seasons in five of the nine regions surveyed. Combining the occurrence of the two leaf diseases indicates that at some stage all regions have experienced infections of at least one of these two diseases. The remaining diseases specifically occur in only one or two regions.

The widest range of diseases are encountered in the warm, humid sub-tropics and tropics of Qld. Disease severity is also highest in Qld, with the heaviest disease pressure being experienced in Bundaberg. A similar pattern emerged in an earlier sweet corn project, VG436, where *Turcicum leaf blight* was frequently observed in varieties which rarely succumbed to this disease in either the Lockyer Valley in SEQ or the Bowen-Burdekin area in NQ.

The survey revealed that crop scouting was practised in all regions, either via crop consultants, in-house consultants or by growers utilizing their own experience and knowledge of their region. This practice allows early recognition of disease symptoms so that remedial action, such as applying an appropriate fungicide, can be implemented. The survey indicated that this strategy was adopted in all regions by at least some growers.

The frequency of disease occurrence and intensity of fungicide applications reflect the importance of the two leaf diseases mentioned above in the various regions. That little impact on sweet corn production is experienced from disease infestations is a reflection on how well variety selection has been adopted by growers in implementing their IPM systems. It also reflects how well breeding programs have been able to incorporate resistance to several diseases common in Australia which, particularly in the temperate areas of the country all but remove the necessity to apply fungicides.

### 6.31 Diseases in the Australian Sweet Corn Industry - Discussion

The data gathered indicates that, while a significant number of diseases are present throughout the industry in Australia, few of the diseases mentioned by growers in the survey occur extensively throughout the geographic spread of the industry. The best known and most widely distributed of the diseases mentioned were Turcicum leaf blight and Common rust and the general area of soil-borne diseases/establishment problems (which in many cases may be due to soil insects as such problems are difficult to diagnose). The two leaf diseases have occurred in crops in at least some seasons in five of the nine regions surveyed. Combining the occurrence of the two leaf diseases indicates that at some stage all regions have experienced infections of at least one of these two diseases. The remaining diseases specifically occur in only one or two regions.

The widest range of diseases is encountered in the warm, humid sub-tropics and tropics of Qld. Disease severity is also highest in Qld, with the heaviest disease pressure being experienced in Bundaberg. A similar pattern emerged in an earlier sweet corn project, VG436, where *Turcicum leaf blight* was frequently observed in varieties which rarely succumbed to this disease in either the Lockyer Valley in SEQ or the Bowen-Burdekin area in NQ.

While the largest effects on production were reported as high as 30%-50% from the effects of Turcicum leaf blight in the Bundaberg area, none of the diseases currently have a major impact on the overall Australian sweet corn production. A key to this is the range of management practices available to growers to manage these diseases. Integral to these practices is the widespread adoption of Integrated Pest Management (IPM).

The survey revealed that crop scouting was practised in all regions, either via crop consultants, in-house consultants or by growers utilizing their own experience and knowledge of their region. This practice allows early recognition of disease symptoms so that remedial action, such as applying an appropriate fungicide, can be implemented. The survey indicated that this strategy was adopted in all regions by at least some growers. The frequency of disease occurrence and intensity of fungicide applications reflect the importance of the two leaf diseases mentioned above in the various regions.

**Varieties Grown in Australia**

The number of varieties is very small given the range of climates and environmental conditions experienced through the surveyed areas. This is possibly a response to market demand for a particular style of product rather than the varieties being particularly well adapted to such a wide range of environmental conditions.

The variety most widely grown, Goldensweet Improved, enjoys a high level of market acceptance and produces well over a wide range of environments. This is dependent upon growers selecting the period of least Turcicum blight pressure as the variety has a low level of tolerance to this disease.

That little impact on sweet corn production is experienced from disease infestations is a reflection on how well variety selection has been adopted by growers in implementing their IPM systems. It also reflects how well breeding programs have been able to incorporate resistance to several diseases common in Australia which, particularly in the temperate areas of the country all but remove the necessity to apply fungicides.

**Conclusion**

http://www2.dpi.qld.gov.au/horticultureresearch/18739.html

The survey provided a snapshot of pest and disease management practices as well as some additional information on general cultural practices, some statistical information and important information sources for growers. Additionally, the information was gathered from a significant section of the industry ranging over a broad area of Australia. While this report concentrated on diseases and their severity, additional information gathered will be of use in formulating strategies for the conduct of the remaining period of the project.

The survey has shown that while there are a significant number of diseases which growers need to contend with across Australia, the range of strategies they employ to manage the risk posed by these diseases is generally very effective.

Strategies include :-

- Monitoring crops,
- selecting varieties with appropriate resistances,

- scheduling less resistant varieties at times when environmental conditions are less favourable for disease development, and
- applying fungicides, if necessary, at critical times and appropriate frequencies

All contribute to managing the risk of crop damage and consequent reduced productivity.

What also appears obvious is the range of germplasm utilized tends to favour production in the more temperate regions, while the sub-tropical to tropical environments require more intensive management as a result of the limited range of germplasm with tropical adaptability. The industry in Queensland, while only extending northwards into the dry tropical zone, is very deficient in adaptable material to extend the industry further north onto the Atherton Tableland, a fertile, irrigated expanse of productive soils which will come under stronger demand in the future, given the scant water availability in some of our southern production areas.

### 6.32 North Queensland - Disease Management - Discussion

Turcicum Leaf Blight *(Exserohilum turcicum)*, occurs every season in north Queensland and causes minor yield losses of less than 5%. Disease pressure is highest in the autumn-winter period and higher in the Burdekin area than in the Bowen area.. In this trial in 2007, all the varieties had relatively low disease severity. Control is achieved (when infection occurs at much higher levels than experienced in this trial), by applying fungicides chlorothalonil (e.g. Bravo™), or occasionally propoconazole (Tilt™).

The impact from disease infestations on sweet corn production is quite low, a reflection on how well variety selection has been adopted by growers in implementing their IPM systems. It also reflects how well breeding programs have been able to incorporate resistance to several diseases common in Australia which, all but remove the necessity to apply fungicides.

It also reflects the fact that all production districts (including North Queensland) have been affected by varying levels of drought for many years.

## 6.40 Toxicity of three "soft options" insecticides against a range of beneficials – Discussion.

This study showed different toxicities for the five insecticides tested against the three beneficial species representative of the Coccinellidae (*Coccinella transversalis* Fabricius) - Transverse ladybird; *Cryptolaemus montrouzieri* Mulsant)- Mealybug predator, Neuroptera (*Mallada signata* (Schneider)) - Green Lacewing and Chalcidoidea (*Trichogramma pretiosum* Riley) - Helicoverpa parasite.

**Coleoptera : Ladybirds (*Cryptolaemus montrouzieri, Coccinella transversalis)***

Spirotetramat was classified as harmless, with no further testing required. Flubendiamide, chlorantraniliprole and spinosad were rated as slightly harmful to adult *C. montrouzieri* in laboratory trials, and in semi-field conditions, only chlorantraniliprole was found to be slightly harmful. Based on exposure to residues, none of the new insecticides were regarded to be toxic to *C. transversalis*.

**Neuroptera: *Mallada signata***

Flubendiamide and chlorantraniliprole were classified as slightly harmful, spirotetramat moderately harmful, and spinosad harmful to first instar *M. signata* when exposed to residues in the laboratory. *M. signata* pupation was also affected.

**Hymenoptera: *Trichogramma pretiosum***

The mortality of *Trichogramma* pupae when parasitised host eggs were exposed to spinosad was very high, with successful eclosion reduced by 91.4%. According to the IOBC guidelines, spinosad is rated 'moderately harmful'.

This study showed different toxicities for the five insecticides tested against the three beneficial species representative of the Hymenopteran, Coleopteran and Neuropteran orders.

**Coleoptera : Ladybirds (*Cryptolaemus montrouzieri, Coccinella transversalis)***

According to the IOBC classification system, spirotetramat was classified as harmless (category 1), with no further testing required. Flubendiamide, chlorantraniliprole and spinosad were rated as slightly harmful (category 2) to adult *C. montrouzieri* in laboratory trials. However, after further testing under semi-field conditions, only chlorantraniliprole was found to be slightly harmful. Following IOBC guidelines, adult *C. montrouzieri* should be subjected to additional semi-field and/or field tests to further examine its susceptibility to chlorantraniliprole. Based on exposure to residues, none of the new insecticides were regarded to be toxic to *C. transversalis*.

**Neuroptera: *Mallada signata***

Flubendiamide and chlorantraniliprole were classified as slightly harmful (category 2), spirotetramat moderately harmful (category 3), and spinosad harmful (category 4) to first instar *M. signata* when exposed to residues in the laboratory. *M. signata* pupation was also affected, with larvae exposed to spinosad taking longer to emerge than the control, whilst larvae exposed to chlorantraniliprole emerged more quickly. Two larvae exposed to spinosad emerged, but died shortly after pupation, whilst three larvae exposed to chlorantraniliprole failed to emerge. Further testing under semi-field conditions with 2$^{nd}$-instar larvae did not show any significant differences between treatments in terms of mortality, though pupation was not measured.

**Hymenoptera: *Trichogramma pretiosum***

The mortality of trichogramma pupae when parasitised host eggs were exposed to spinosad was very high, with successful eclosion reduced by 91.4%. According to the IOBC guidelines, spinosad is rated 'moderately harmful' (category 3). Toxicity was characterised by the death of the parasitoids during their teneral stage. Either no emergence hole was evident, or death occurred soon after the parasitoid opened an emergence hole in the host chorion. This suggested ingestion of the chemical by the parasitoid might occur during the opening of the emergence hole. When cutting a small area of the host chorion with its mandibles, it is probable that a quantity of the chorion surface could be swallowed and with it the insecticide residual the host surface was exposed to (Consoli et al. 2001; Croft & Brown, 1975). These results were supported by Consoli *et al*. (2001) who had similar findings for spinosad. Spinosad was also found to be highly toxic to all parasitoid species by Tillman and Mulrooney (2000), however their study involved topical application of the insecticide, where adults were directly sprayed in our study.

**Further research**

Few studies have been published on the effect of the spirotetramat, flubendiamide and chlorantraniliprole on beneficial insects. Tohnishi *et al.* (2005) investigated the toxicity of flubendiamide on a range of beneficials including *Harmonia axyridis, Coccinella septempunctata bruckii, Cotesia glomerata, Encarsia formosa, Aphidius colemani* and *Chrysoperla carnea*, and found it to be inactive at 100 to 400 mg/L. Tohnishi *et al.* (2005) concluded that flubendiamide was very safe for natural enemies and was therefore suitable for use in IPM programmes. Although our testing suggests that spirotetramat and flubendiamide are likely to be compatible with beneficials, further research is necessary to provide more information on the toxicity of these insecticides. Assessments should include evaluations of other beneficials such as *Hippodamia variegata*, brown lacewing (*Micromus tasmaniae*), predatory mites (*Phytoseius persimilis*) which are commonly found in sweet corn, and the effects on a range of life stages such as egg-larval, larval, pre-pupal and pupal stages to assess delays in developmental time from egg to adult when treated at different immature stages. The side-effects of insecticides on newly emerged trichogramma adults from treated parasitised eggs should also be assessed, by measuring the parasitisation capacity (number of eggs parasitized/female/time), adult survival, and successful progeny emergence. Adult stages of parasites have been shown to be the most susceptible to insecticides, as they are often the only stage to live an exposed life (Croft & Brown, 1975).

## Disclaimer:

***A range of insecticides are referred to in this report. Where an insecticide is named together with ™ as a superscript, this refers to the insecticides' Registered Trade Name. This DOES NOT imply that this insecticide is registered for use on sweet corn in Australia. It is important that the registration status of all insecticides are verified prior to their application to sweet corn in Australia.***

# 7.00 Technology Transfer

## 7.10 Sweet Corn IPM – Bowen September 2007

A very successful Field Day was held on the afternoon of 19th September at Bowen Research Station with some 20 people in attendance. The focus of the afternoon was a sweet corn variety trial conducted as part of the project.

Present were all sweet corn growers in the region along with key members of their staff, agribusiness representatives, seed company agronomists, private consultants and DPI&F staff. Attendees had travelled from as far south as the mid north coast of NSW to as far north as the Atherton Tableland in North Qld.

The afternoon commenced with an address by Ross Wright, Senior Horticulturist, DPI&F, Bowen, who gave an introduction and outline of the project and its funding sources. He provided a brief discussion of the trial on display and explained that data was collected on a range of attributes of the varieties under test, from emergence and establishment, flowering and cob maturity time to incidence of diseases and pests.

Dr. Siva Subramaniam then addressed the gathering and outlined his role in the project on secondary insect pests and some additional work on a major pest. He provided an update on his work so far in the project and the additional studies being conducted with the funds provided by the chemical company voluntary contributors and matched by HAL.

This was followed by a viewing of the trial and the sample cobs previously harvested and displayed adjacent to the trial. The seed company representatives who contributed varietal material for testing in the trial were then invited to discuss their breeding programs and material in the trial. Following these addresses, further inspections of trial plots and cob samples displayed was undertaken. The field day terminated in the late evening.

Dr Siva Subramaniam addressing the field day attendees.

Cob samples from the trial plots displayed on tables.

## 7.20 Sweet Corn IPM – Yanco NSW – May 2007

News

AGRICULTURE TODAY ■ Thursday, May 31, 2007 5

Primary Industries

# New weapons, old war

EFFICACY trials have revealed two promising insecticides that fit Integrated Pest Management (IPM) protocols for sweet corn growers in the perpetual war on invading insect pests, particularly heliothis.

Both are narrow spectrum insecticides in the experimental stage, being developed by different chemical companies.

"They gave excellent control of heliothis, the major insect pest of sweet corn," NSW Department of Primary Industries (DPI) district horticulturist, Tony Napier, said.

"The level of control was as good as any other insecticide currently registered for use."

NSW DPI has evaluated the insecticides with the sweet corn industry and chemical companies.

Left uncontrolled, heliothis can decimate a crop, doing the most damage about two months in, when cobs are beginning to form.

"The presence of beneficial insects in sufficient quantities will control heliothis without any insecticide," Mr Napier said.

"If beneficials are present, but in numbers too low for adequate control, growers will require a narrow spectrum insecticide."

A technical officer at Yanco specialising in IPM systems for vegetables, Adelle Dunn, has been evaluating the new generation insecticides for their effect on all the insects found in sweet corn.

"We had a good range of beneficial insects in our trials this year and it was pleasing to see the two new insecticides had little effect on them," Ms Dunn said.

"Ladybird beetles, pollen beetles and pirate bugs were all present in high numbers in the trial and the new insecticides had little effect on them.

"It is important to try to preserve these insects in the crop, as they will clean up any heliothis invading after the insecticide applications."

Mr Napier said the research results from these trials will help chemical companies register the new narrow spectrum insecticides.

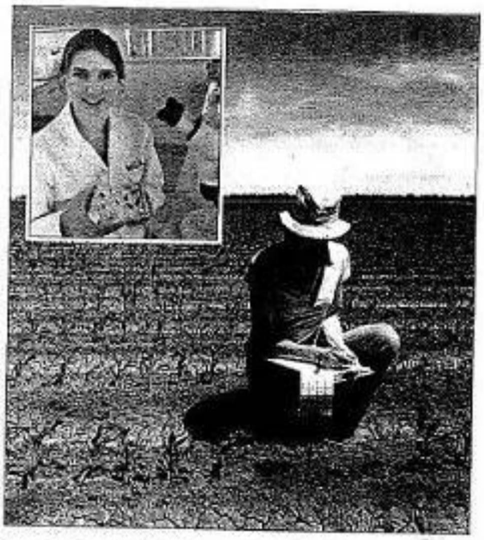
"If we want to continue winning the war against heliothis, it is important to continue developing new insecticides for all crops, not only sweet corn," he said.

"A greater range of choice will help avoid heliothis developing insecticide resistance."

According to Mr Napier, narrow spectrum insecticides are a lot softer on non-target insects than the older generation broad spectrum insecticides.

Where broad spectrum insecticides kill almost all insects present in a crop, narrow spectrum insecticides only kill the target pest and have minimal effect on the other insects.

■ **Contact Tony Napier, Yanco, (02) 6951 2796.**



**RIGHT:** Yanco technical officer Adelle Dunn, checking the sweet corn trials for pest and beneficial insects at the seedling stage and (inset) in the laboratory with insects she collected.

# Adapting against the aphid

LETTUCE growers have had to adapt quickly to combat currant-lettuce aphid.

Most have chosen to use new resistant varieties; some are applying a new chemical and a few are trying beneficial insects.

"Currant-lettuce aphid is primarily a problem as a contamination pest," Dr Sandra McDougall, leader of the national Let-

"This chemical is applied to seedlings prior to transplanting," Dr McDougall said.

"This protection only works when applied properly and when not over-watered."

"Another option is allowing beneficial insects to clean up the aphid but growers need to manage all their pests mindful of preserving the beneficials."

ving commercial-scale plantings.

The trial used IPM principles in collaboration with an IPM consultant, Dr Paul Horne, and the collaborating researcher.

Monitoring data was collected and at harvest a quality assessment was made counting all infesting aphids or beneficial insects within 15 to 30 lettuce heads.

**Making News**

## DPI research nominees

TWO of three finalists nominated in the Researcher of the Year award at the Australian Vegetable Industry conference as *Agriculture Today* went to press were from the NSW Department of Primary Industries.

The event was staged at Darling Harbour, with the

### 7.30 Web Site

http://www2.dpi.qld.gov.au/horticulture/18247.html (accessed 18th Feb 2009).

This web site was established to provide information on the Australian sweet corn industry, including IPM Project information.

# Sweet corn

## Queensland's sweet corn industry

Queensland supplies the fresh markets of Brisbane, Sydney and Melbourne, and a freezing and canning plant in Brisbane. Approximately half of Queensland's sweet corn production is processed. In the year to 30 June 2002, Queensland produced 30,226 tonnes of sweet corn worth about $28.8 million. This represents about 38% of the Australian production (80,467 t) and 55% of its value ($52.7m). Queensland's crop was grown on 2,719 hectares of Australia's total of 6,956 ha under sweet corn (Source: ABS).

The processing plant is supplied from the Lockyer Valley, which also supplies the fresh market, and harvests between November and June. The other main production regions are around Bowen (May to November) and Bundaberg (April to July and October to December).

Most sweet corn is sold on the Australian domestic market, but there is increasing interest in the export markets of south east Asia. Japan takes over 90% of our export sweet corn with the rest going to New Zealand and Singapore (Source: Austrade). Any growth in production will depend on access to export markets. Because of the high capital costs involved, a small number of large growers produce 80 to 90% of production.

## Research and development information

Projects currently and recently managed by DPI&F include:

## Current projects

Improved IPM systems in the Australian sweet corn industry (VG05035)

This project aims to improve Integrated Pest Management (IPM) systems currently used in the Australian sweet corn industry to manage a range of 'secondary pests,' whilst maintaining or improving helicoverpa management. Project updates will be made available as milestones are completed. The following links provide information on some outputs so far:

- reactions of commercial sweet corn varieties to turcicum leaf blight and common rust

## Recent projects

Insect pest management in sweet corn (VG97036)

This national project on integrated pest management in sweet corn was recently completed. This site provides information and updates from the project.

# Crop information

Enterprise management

This page contains business information, including buying a farm, producing vegetables for market, chemical use and drought information.

Growing sweet corn: Before you start

This DPI&F Note is a checklist of the things you need to know before you start. It will help you make the right decision about growing sweet corn.

Growing sweet corn: Common questions

This DPI&F Note contains answers to the most common questions asked about growing and marketing sweet corn in Australia.

# Pests, diseases & beneficials

Egg parasitoids of helicoverpa

This DPI&F Note discusses trichogramma and *Telenomus* wasps as important biological control agents of helicoverpa, how to detect and monitor them and how best to conserve them.

Helicoverpa in sweet corn

This DPI&F Note discusses helicoverpa (*Helicoverpa armigera*), also known as corn earworm, the most important pest of sweet corn.

IPM: Using NPV to manage helicoverpa in field crops

This page discusses nucleopolyhedorvirus (NPV), how it works, how best to use it and what you can expect it to do.

White collared ladybird predator in vegetable crops

This DPI&F Note includes pictures and discusses the lifecycle and effectiveness of this aphid predator.

# Industry links

The sweet corn industry is represented by AUSVEG, who support the DPI&Fs sweet corn research and industry development projects.

There are many other industry groups representing the horticulture sector, visit our industry links page for links to many of their websites.

## External references

The following web sites are external to the DPI&F site but contain information our sweet corn specialists consider would be of interest to Australian growers.

The Australasian Biological Control web page provides links to commercial suppliers of bio-control agents and lists the products they sell.

Growing sweet corn is a useful publication produced by New South Wales Agriculture, part of the NSWDPI.

How a corn plant develops published by the Iowa State University of Science and Technology is a good explanation of the botany and growth of corn.

Purdue University has a page of useful sweet corn links.

The University of California's IPM Online web site provides information on a wide range of insect, mite, disease and weed pests.

VegetableIPM is a site being developed to assist growers and consultants who want to reduce chemical use and manage pests more cost effectively.

## DPI&F information and services

- To access DPI&F's information and services, Queensland residents can contact the **DPI&F Business Information Centre** on **13 25 23** for the cost of a local call, from 8 am to 6 pm Monday to Friday (excluding public holidays). E-mail callweb@dpi.qld.gov.au. Non-Queensland residents phone (07) 3404 6999.
- Current national information on agricultural chemicals registered for use on all crops is available on the Infopest CD-ROM. Write to DPI&F, GPO Box 46, Brisbane, Qld 4001, E-mail infopest@dpi.qld.gov.au, visit the Infopest web page, or phone (07) 3239 3967 for further information.

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Last updated 19 September 2007

## Consumer information

### Sweet corn nutrient content

These pages contain general information on sweet corn and its health benefits.

Food Standards Australia and New Zealand has information on the nutrient content of a wide range of foods including fruit and vegetables.

The USDA Nutrient Database for Standard Reference provides information on the nutrient content of a wide range of foods including sweet corn.

Fresh for kids - corn is a web page about corn and sweet corn written for kids.

The world's healthiest foods web site has a page on sweet corn.

## Saleable publications

The following publications would be valuable assets to anyone interested in the Australian sweet corn industry.

### Growing guide


Sweet corn grower's handbook

This book discusses growing and marketing fresh market and processing sweet corn. It is an essential, best practice reference for the Australian sweet corn industry. A link on this page lets you buy the book online.

### Picture guide


Sweet corn problem solver & beneficial identifier

This book is designed to help you identify and where possible manage sweet corn pests, diseases and disorders, and identify beneficial insects and spiders, the natural enemies of sweet corn pests. A link on this page lets you buy the book online.

**IPM field guide**


Sweet corn insect pests and their natural enemies

This guide draws on the experiences and observations of crop consultants, growers and scientists. It includes notes on integrated pest management, crop monitoring, major and secondary insect pests, and the major natural enemies of these pests.

## Disclaimer:

***A range of insecticides are referred to in this report. Where an insecticide is named together with ™ as a superscript, this refers to the insecticides' Registered Trade Name. This DOES NOT imply that this insecticide is registered for use on sweet corn in Australia. It is important that the registration status of all insecticides are verified prior to their application to sweet corn in Australia.***

# 8.00 **Recommendations** (scientific and industry)

Recommendations are divided into two categories. The first recommendations are those which have arisen from the project work program and outcomes. The second are recommendations which apply to the wider sweet corn industry, and put into context those which have arisen from the project work program and outcomes.

## 8.10 Recommendations arising from the work program and outcomes of VG05035.

**8.11 Five (5) additional 'soft options' have potential, and registration should continue to be pursued** on behalf of the Australian sweet corn industry :-

- Movento™ and SCSI-03b (no trade name allocated) were effective against sucking insects (thrips and aphids). These new sap sucking pests 'soft options' insecticides do appear to have some impact on beneficial arthropods, although they do not appear to affect trichogramma populations.
- Both Belt ™ and Coragen ™ are very effective against helicoverpa and Sorghum Head Caterpillar and appear to have low impact on beneficial insects.
- The miticide, Paramite™, has suppressed 2-spotted and red spider mite populations. These new insecticides and miticide do appear to have minimal impact on beneficial arthropods.

**8.12 Appropriate guidelines for managing insecticide resistance in sweet corn pests should be implemented** at regional level, when registration of these soft options occurs.

**8.13 Additional investigations are required to determine the impacts of these five (5) "soft options" (Movento™ and SCSI-03b (no trade name allocated, Belt™ , Coragen™ and Paramite™) on beneficial arthropods.** Assessments in this project indicate a low impact.

**8.14 Determine the contribution of naturally occurring beneficial arthropods** including brown and green lacewings, ladybirds, spiders and damsel bugs, **which occur regularly in sweet corn fields**. Project results indicate that their contribution to the biological control of helicoverpa and sucking pests is important, but quite variable from season to season and field to field.

**8.15 For the processing sweet corn industry** in southern Australia :-

**i)** Where broad spectrum insecticides are used in rotation with Success™, **it is recommended that higher water rates be applied by a boom fitted with droppers**, as this treatment gave significantly better results than applying the insecticides at lower water rates with no droppers fitted.

**ii) At silking, rotating the 'soft option' Coragen™ with Success™ is recommended**, as it provides significantly greater helicoverpa control, and will reduce the resistance pressure on both insecticides.

**8.16 For the Australian sweet corn industry** :-

**i) The protection of naturally occurring beneficials (natural enemies) is an essential component of sweet corn integrated pest management.** This is particularly the case in tropical and sub-tropical production districts, where pest pressures are much higher, and the benefits of beneficials in particular seasons are very high. In temperate production districts, where pest pressures are often not as high, and beneficials numbers are low and sometimes absent, the benefits have been shown, although not as high as in northern regions. It is expected that natural enemies are likely to be more prevalent and therefore more effective, when the `softer' insecticides are available and incorporated into IPM systems.

**ii) Monitoring of pests and beneficials for decision making purposes is an essential component of sweet corn integrated pest management.** This is especially the case for those IPM systems which have heavily utilised soft options and reduced the use of broad spectrum insecticides.

**iii) Document the benefits and costs, including the barriers to implementation of IPM, most particularly in temperate production regions**, as pest management (including helicoverpa) is still an issue for the industry. There are additional control options available as a result of the IPM projects funded over the past 10 years, but there is only a limited application of the outcomes of this IPM R&D in temperate production regions (in contrast to tropical and sub-tropical regions of Australia). In the processing industry, this is because of the costs of IPM components, particularly the new 'soft options', which are considered too expensive or inappropriate to be included as a part of the standard pest management system.

**iv) The impact of disease infestations on sweet corn production is quite low.** Variety breeding and selection programs need to continue to maintain and improve on the current level of disease resistance. This is necessary to enable the industry to maintain its current low level of dependence on the application of fungicides, and is particularly important in face of the low incidence of diseases generally, as all production districts have been affected by varying levels of drought for many years.

## 8.20 Recommendations which apply to the wider sweet corn industry, and put into context of those which have arisen from the project work program and outcomes.

**Profitability** will continue to be an issue in the sweet corn industry in Australia. Increasing profitability will be necessary to enable processors and growers (both processing and fresh market), to compete on the export and domestic market. This is the overarching issue for the sweet corn industry, as it is for most vegetable commodities. This can be achieved only by <u>reducing the costs and the risks of production, transport and marketing, and/or increasing yields</u> without significantly increasing costs of production.

**Improved Integrated Pest Management Systems** are an important part of reducing the risks of production and marketing. Pest management remains an issue, especially in southern regions, and especially in the processing market (where cost constraints have reduced the uptake of IPM technologies from past R&D).

The fresh market and processing industries need to be distinguished from each other on the basis of the following significant differences – Cultivars; Location and time of the year of production; Agronomy and costs of production (particularly pest management and irrigation) and Products and markets.

Frozen sweet corn is not processed in Australia currently because of competition from imports. Simplot is the only sweet corn processor (canning) in Australia.

The following are considered to be the important issues (including continued R&D in IPM) for the Australian sweet corn industry.

**<u>It is recommended that the sweet corn industry consider the following issues for further R&D investment</u> :-**

**8.21** **<u>Increase sweet corn productivity and profitability</u>** through increased yields per unit of input and per plant. Has sweet corn productivity reached its yield limit? Can sweet corn be bred or manipulated to produce multi-cobs with synchronous maturity for once over mechanical harvesting? Under some environmental conditions, multiple cobs are produced, and do reach synchronous maturity. This needs to be better understood and exploited where possible.

**8.22** **Near Infra-red Technologies** for inline scanning for damaged cobs is a proven technology. The step to commercialising to reduce the high labour costs in the packing shed for checking sweet corn cobs for end fill and damage prior to packing' has not be followed through.

**8.23** **Document the benefits and costs, including the barriers to implementation of IPM, most particularly in temperate production regions**, as pest management (including helicoverpa) is still an issue for the industry. There are additional control options available as a result of the IPM projects funded over the past 10 years, but there is only a limited application of the outcomes of this IPM R&D in temperate production regions (in contrast to tropical and sub-tropical regions of Australia). In the processing industry, this is because the costs of IPM components, particularly the new 'soft options', are considered too expensive to be considered a part of the standard pest management system.

**8.24** **Investigate the cause and solutions to poor 'end fill'** – this is a production issue associated with some susceptible cultivars and environment (high temperature and low humidity at silking) and pest management, and will be exacerbated by future climate change.

**8.25** **Investigate the health benefits of sweet corn** to increase consumption of sweet corn as a functional food.

**8.26** **Increase the domestic market for white and bicolour sweet corn** which will lead to increased export opportunities. There is a demand for export white and bicolour sweet corn, but the opportunities to access this export market are limited by the small domestic market with the consequent limited production levels on which to base an export production and marketing system.

**8.27** **Prepare for climate change** by developing adaptation strategies and understanding impacts of climate change and climate variability on the sweet corn industry – (viz. pollination, product quality, yield, location, water supply, etc), as maximum temperatures continue to rise.

**8.28** **Build and maintain soil health** through research and extension activities.

## Disclaimer:

***A range of insecticides are referred to in this report. Where an insecticide is named together with ™ as a superscript, this refers to the insecticides' Registered Trade Name. This DOES NOT imply that this insecticide is registered for use on sweet corn in Australia. It is important that the registration status of all insecticides are verified prior to their application to sweet corn in Australia.***

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# 11.00 Appendices

## Appendix 1. – Milestone Report #3. - Sweet Corn Diseases and their Severity in Australia - November 2006

Contributors:
Ross Wright[4], Andrew Watson[2], Sonya Broughton[3], Jerry Lovatt[5], and Peter Deuter[1]
[1]QLD DPI&F, Gatton Research Station,
[2]NSW DPI, Yanco Agricultural Institute, Yanco NSW 2703
[3]Western Australia Department of Agriculture
[4](formerly) QLD DPI&F, Bowen Research Station
[5] QLD DPI&F, Bundaberg Research Station

**Introduction**

A survey of growers in the major production districts through Queensland, New South Wales, Victoria, Western Australia and Tasmania was conducted principally to determine the range of sweet corn diseases encountered and their severity. The survey was conducted by face to face interviews, telephone interviews and in a few instances by initial telephone contact and facsimile for data collection.

While the major focus of the survey was to gather information on sweet corn diseases, the opportunity was taken to update information on secondary pests and the longer term impact of the previous project, *Insect Pest management in Sweet Corn*, VG 97036. A common questionnaire was used to structure interviews. Data was collected on diseases, pests and measures used to manage them; sources of information; crop management factors and additional skills and knowledge required; and the most desirable method of delivering information from this project to industry members.

***Range of Diseases reported by growers***

(several common names are used for some of the diseases)

Turcicum leaf blight or Northern leaf blight - *Exserohilum turcicum*

Rust or Common rust - *Puccinia sorghi*

Yellow leaf blight (unknown causal organism, but possibly Southern leaf blight or Maydis leaf blight) - *Bipolaris maydis*

Charcoal rot or Ashy stem blight - *Macrophomina phaseolina*

Boil Smut or Common smut - *Ustilago zeae*

Wallaby ear – initially thought to be a virus infection, but now known to be from a toxin injected by leafhoppers while feeding. Causes stunting and stiffening of plants.
Plants grow away when leafhoppers are controlled.

Mosaic - Johnson Grass Mosaic Virus (JGMV)

Soil-borne diseases - various fungi (e.g. fusarium, pythium, rhizoctonia)

Nematodes, root lesion nematodes - *Pratylenchus zeae*

The current regional distribution, severity and techniques growers use to manage these diseases are presented in Table 1. All production, with the exception of the NSW processing crops and 10% of the SEQ production, was for the fresh market.

**Table 1**

***Sweet corn diseases distribution, severity and management***

| Region | Incidence and Severity | Management Methods reported by growers |
|---|---|---|
| ***DISEASE*** | ***Turcicum Leaf Blight (Exserohilum turcicum)*** | |
| North Queensland (Bowen-Burdekin) | Occurs every season and causes minor yield losses of less than 5%. Disease pressure is highest in the autumn-winter period and higher in the Burdekin area than in the Bowen area. | Spray crops with fungicides chlorothalonil (e.g. Bravo), or occasionally propoconazole (Tilt). Growers select varieties with highest resistance for highest pressure periods. |
| Central Qld (Bundaberg) | Occurs every season and causes yield losses in the vicinity of 30% – 50%. The disease is present throughout the growing season. | Apply fungicide sprays of chlorothalonil at 10 day intervals. Selecting the most resistant varieties for the highest pressure period is a practice. |
| South-east Qld (Lockyer-Fassifern Valleys, Eastern Darling Downs) | Only occasional problem, causes less than 1% yield loss. | 50% of growers apply chlorothalonil when weather is conducive or disease is prevalent. Growers use variety with high resistance for summer harvests and least resistant in early spring sowings. |
| NSW Sydney Basin | Occurs 1 season in 3 and causes yield losses of less than 10% in those seasons. Accounts for 30% of disease problems in this region. | Not usually sprayed for but when severe 20% of growers spray 1-2 times. Use chlorothalonil or propoconazole. Growers use more susceptible varieties early in season (autumn) and the more tolerant later. |
| NSW processing Cowra-Bathurst | Not considered a problem | |
| Victoria | Not considered a problem | |
| Victoria – Lindenow district | Not considered a problem | |
| Tasmania | Not considered a problem | |
| Western Australia | Rarely or never a problem, but when it occurs yield losses of 20-30% result. | All growers indicated they select varieties with resistance to diseases. |

| Table 1 (cont) Region | Incidence and Severity | **Management Methods** reported by growers |
|---|---|---|
| ***DISEASE*** | ***Common Rust (Puccinia sorghi)*** | |
| North Queensland (Bowen-Burdekin | Only a problem in some minor varieties used for niche markets. Occurs more in the Burdekin area than Bowen. | When it occurs, controlled by propoconazole when used for leaf blight. Restriction with 28 day withholding period. Select varieties with resistance where possible. |
| Central Qld (Bundaberg) | Mentioned as a leaf disease occurring but no details are mentioned. | Sprays with sulphur at the same frequency as Bravo for leaf blight which would provide control. Variety selection used probably eliminates rust as a problem |
| South-east Qld (Lockyer-Fassifern Valleys, Eastern Darling Downs. | Not considered a problem | |
| NSW Sydney Basin | Not considered a problem | |
| NSW processing Cowra-Bathurst | Mentioned by a third of growers as a leaf disease, but rarely or never seen overall. When it occurs, yield losses of less than 10% are estimated to occur. | All growers indicate that when the disease occurs they spray to control it. The only fungicide mentioned is chlorothalonil. Varieties and sowing schedules are selected by the processors. |
| Victoria | For 20% of growers, rust occurs 1 season in 5 or less, while 80% never or rarely see it. When it occurs, yield losses are estimated at less than 5%. | Only 10% of growers need to spray to control the disease. Growers who experience the disease choose resistant varieties. Most growers don't need to undertake any specific management for rust control. |
| Victoria – Lindenow district | Growers experience rust 1 year in 5 or less with yield losses when it occurs at less than 5%. | Fungicide sprays are used when necessary (propoconazole). Growers choose varieties with best tolerance to rust. |
| Tasmania | Not considered a problem | Uses plastic mulch and trickle irrigation to reduce opportunity for leaf diseases. |
| Western Australia | Not considered a problem | |

| Table 1 (cont)<br>Region | Incidence and Severity | **Management Methods**<br>reported by growers |
|---|---|---|
| ***DISEASE*** | ***Yellow Leaf Blight (probably Southern leaf blight - Bipolaris maydis)*** | |
| North Queensland Bowen-Burdekin | Occasional disease, occurs 1 season in 5, mostly in the Burdekin area in early and mid season. Only reported in NQ in the survey. | No management techniques available specifically for this disease. |
| ***DISEASE*** | ***Charcoal Rot, Ashy stem blight (Macrophomina phaseolina)*** | |
| North Queensland Bowen-Burdekin | Sporadic disease in the Burdekin area late in the season. Occurs as a rot in the tassel and sometimes as a stem disease. Only reported in NQ in the survey. | Disease is exacerbated by stress factors. Try to manage stress effects in harsher seasons. |
| ***DISEASE*** | ***Boil Smut, Common Smut (Ustilago zeae)*** | |
| South-east Qld (Lockyer-Fassifern Valleys, Eastern Darling Downs | Increasing problem especially when conditions are moist. Worst disease problem in this region. Occasionally a stem rot causing less than 1% loss, but most often a cob rot causing less than 5% loss but contaminates packing shed machinery. | No specific management techniques available. |
| NSW Sydney Basin | Causes less than 10% yield loss 1 season in 3. Accounts for 70% of disease problems in this region.<br>Only reported in SEQ and the Sydney basin in this survey. | No specific management techniques available. |
| ***DISEASE*** | ***Wallaby Ear*** | |
| South-east Qld (Lockyer-Fassifern Valleys, Eastern Darling Downs<br>. | An occasional problem which can severely stunt plants if not managed and potentially reduce yields. Severity of the disease (toxin affect) depends on the leafhopper numbers on the plant. | Controlling the leafhopper vector (*Cicadulina bimaculata)* will eliminate the disease as the insect needs to be continually feeding on the plant to cause the effects.<br>Dimethoate sprays are used to control the pest but the chemical is very disruptive to IPM programs due to its effect on beneficial insects. |
| ***DISEASE*** | ***Mosaic - Johnson Grass Mosaic Virus (JGMV)*** | |
| South-east Qld (Lockyer-Fassifern Valleys, Eastern Darling Downs | Very susceptible hybrids show extensive yellowing and early infection often results in severe stunting and yield reduction. Aphid transmitted virus, the main host being Johnson grass. Also survives in stand-over forage and grain sorghum crops. Does not cause yield losses due to well known management practices. | Growing a resistant hybrid for mid-summer harvests (processing and fresh market) |

| Table 1 (cont)<br>Region | Incidence and Severity | Management Methods<br>reported by growers |
|---|---|---|
| ***DISEASE*** | ***General - Soil-borne diseases, other diseases.*** | |
| North Queensland<br><br><br>South-east Qld. | Overall, soil diseases occur rarely. Fusarium and nematodes have been identified sporadically in the past.<br>Occasional seedling establishment problems caused by rhizoctonia. Less than 1% losses. | Most sweet corn growers use a crop rotation system as a preventative measure.<br>Use crop rotations. |
| NSW-Sydney Basin | Occasional establishment problems in cooler seasons. | Crop rotations are normal part of crop management practices. |
| NSW-processing | No problems encountered. | Two-thirds of growers indicate use of crop rotations from year to year. Others appear to grow sweet corn on same ground each year. |
| Victoria | No problems mentioned. | No information on crop rotations. |
| Victoria-Lindenow | Some establishment problems recorded but non specific.<br>Experience cob disease problems but no details given. | Rotate sweet corn with other vegetable crops.<br>No practices mentioned. |
| Tasmania | Establishment problems mentioned but no specifics. | No cropping details given. |
| Western Australia | No problems encountered. | Rotate corn with other vegetables. |

The data gathered indicates that, while a significant number of diseases are present throughout the industry in Australia, few of the diseases mentioned by growers in the survey occur extensively throughout the geographic spread of the industry. The best known and most widely distributed of the diseases mentioned were *Turcicum leaf blight* and *Common rust* and the general area of soil-borne diseases/establishment problems (which in many cases may be due to soil insects as such problems are difficult to diagnose). The two leaf diseases have occurred in crops in at least some seasons in five of the nine regions surveyed. Combining the occurrence of the two leaf diseases indicates that at some stage all regions have experienced infections of at least one of these two diseases. The remaining diseases specifically occur in only one or two regions.

The widest range of diseases are encountered in the warm, humid sub-tropics and tropics of Qld. Disease severity is also highest in Qld, with the heaviest disease pressure being experienced in Bundaberg. A similar pattern emerged in an earlier sweet corn project, VG436, where *Turcicum leaf blight* was frequently observed in varieties which rarely succumbed to this disease in either the Lockyer Valley in SEQ or the Bowen-Burdekin area in NQ.

While the largest effects on production were reported as high as 30%-50% from the effects of *Turcicum leaf blight* in the Bundaberg area, none of the diseases currently have a major impact on the overall Australian sweet corn production. A key to this is the range of management practices available to growers to manage these diseases. Integral to these practices is the widespread adoption of Integrated Pest Management (IPM).

The survey revealed that crop scouting was practised in all regions, either via crop consultants, in-house consultants or by growers utilizing their own experience and knowledge of their region. This practice allows early recognition of disease symptoms so that remedial action, such as applying an appropriate fungicide, can be implemented. The survey indicated that this strategy was adopted in all regions by at least some growers. The frequency of disease occurrence and intensity of fungicide applications reflect the importance of the two leaf diseases mentioned above in the various regions.

***Varieties Grown***

That little impact on sweet corn production is experienced from disease infestations is a reflection on how well variety selection has been adopted by growers in implementing their IPM systems. It also reflects how well breeding programs have been able to incorporate resistance to several diseases common in Australia which, particularly in the temperate areas of the country all but remove the necessity to apply fungicides.

The range of sweet corn varieties currently grown through Australia in the regions surveyed are listed in Table 2. The number of varieties is very small given the range of climates and environmental conditions experienced through the surveyed areas. This is possibly a response to market demand for a particular style of product rather than the varieties being particularly well adapted to such a wide range of environmental conditions.

**Disclaimer:**

***A range of insecticides are referred to in this report. Where an insecticide is named together with™ as a superscript, this refers to the insecticides' Registered Trade Name. This DOES NOT imply that this insecticide is registered for use on sweet corn in Australia. It is important that the registration status of all insecticides are verified prior to their application to sweet corn in Australia.***

**Table 2**

***Sweet corn varieties by region.***

| Region | Varieties Grown | Usage Comments |
|---|---|---|
| North Queensland (Bowen-Burdekin) | *Goldensweet Improved.*<br><br>*Lancaster, Sentinel, Gladiator.*<br>*Hibrix.*<br><br>*Crunch, Samurai, Everest.* | Major variety grown due to market preference but no visible improvement observed in Turcicum blight resistance over *Goldensweet.*<br>Used instead of *Goldensweet Improved* during periods when Turcicum blight threatens.<br>*Hibrix* used in late season when conditions become harsh. More usage of these alternatives in the Burdekin area where disease pressure is highest.<br>Minor varieties (bicolours, white) grown for niche markets. Also have the least resistance to leaf diseases. |
| Central Qld (Bundaberg) | *Goldensweet Improved,** *Lancaster, Gladiator.* | Lancaster and Gladiator are both preferred over Goldensweet Improved for their higher level of resistance to Turcicum blight. (Market preference requires production of Goldensweet Improved.) |
| South-east Qld (Lockyer-Fassifern Valleys, Eastern Darling Downs) | *Hibrix.*<br><br>*Goldensweet Improved.*<br><br>*Sundry other new varieties for grower trials.* | Tropical variety grown for mid-summer harvests (processing and fresh) for its JGMV resistance and ability to withstand harsh summer conditions.<br>Used for early spring sowings (fresh market only) when JGMV not prevalent. Higher yielding than Hibrix in this period but more prone to Turcicum blight.<br>Looking for varieties with good cob quality and better disease resistance to reduce production risk. |
| NSW Sydney Basin | *Goldensweet Improved.*<br><br>*Magnum,*<br>*Max, Matador* | Planted early in season (October-Nov) during period of least Turcicum blight pressure.<br>These more tolerant varieties planted later in the season when Turcicum blight pressure is higher. Max is a popular variety in this region. |
| NSW processing Cowra-Bathurst | *Punch, Jubilee, Basin, Sovereign.* | Processing varieties chosen by processor, as is the sowing schedule. |
| Victoria | *Goldensweet Improved*, Rising Sun.* | Rust is the only leaf disease of concern listed by these growers and both these varieties have good resistance to rust. |
| Victoria – Lindenow district | *Goldensweet Improved, Gladiator, Rising Sun, Crunch, Obsession.* | With rust being the leaf disease of concern, the suite of varieties chosen (with the exception of *Crunch*) should be quite resistant to rust. |
| Tasmania | *Snosweet.* | Only establishment problems mentioned. Use of trickle irrigation may reduce disease pressure. |
| Western Australia | *Goldensweet Improved *.* | Only variety mentioned |

* While Goldensweet was listed in the survey, it is no longer available and has been replaced by *Goldensweet Improved*

The variety most widely grown, *Goldensweet Improved*, enjoys a high level of market acceptance and produces well over a wide range of environments. This is dependent upon growers selecting the period of least *Turcicum blight* pressure as the variety has a low level of tolerance to this disease. The cob types and leaf disease tolerances of the varieties listed are illustrated in Table 3.

*Table 3*

***Cob types and leaf disease tolerance of varieties from the survey***

| Variety | Cob Type | Turcicum Blight Rating (1-5) | Common Rust Rating (1-5) | Company | End Use |
|---|---|---|---|---|---|
| Goldensweet Improved | Yellow Supersweet | 2 | 5 | Snowy River, Lefroy Valley | Fresh Market |
| Lancaster | Yellow Supersweet | 3 | 5 | Snowy River, Lefroy Valley | Fresh Market |
| Sentinel | Yellow Supersweet | 5 | 5 | Sunland seeds | Fresh Market |
| Gladiator | Yellow Supersweet | 4 | 5 | Snowy River, Lefroy Valley | Fresh Market |
| Hibrix | Yellow Supersweet | 3 | 5 | Pacific seeds | Fresh Market & Processing |
| Punch | Yellow Normal (sugary) | 2 | 3 | Snowy River, Lefroy Valley | Fresh Market & Processing |
| Jubilee | Yellow Normal (sugary) | 1 | 2 | Syngenta | Processing |
| Basin | Yellow Supersweet | 2 | 5 | Seminis | Fresh Market & Processing |
| Sovereign | Yellow Supersweet | 5 | na | Syngenta | Fresh Market & Processing |
| Max | Yellow Supersweet | 4 | 5 | Sunland seeds | Fresh Market |
| Magnum | Yellow Supersweet | 1 | 3 | Syngenta | Fresh Market |
| Matador | Yellow Supersweet | 4 | 5 | Snowy River, Lefroy Valley | Fresh Market |
| Rising Sun | Yellow Supersweet | 2 | 5 | Snowy River, Lefroy Valley | Fresh Market |
| Snosweet | Yellow Supersweet | 5 | na | Snowy River, Lefroy Valley | Fresh Market |
| Crunch | Bicolour Supersweet | 4 | 2 | Snowy River, Lefroy Valley | Fresh Market |
| Samurai | Bicolour Supersweet | 3 | 5 | Snowy River, Lefroy Valley | Fresh Market |
| Obsession | Bicolour Supersweet | 3 | 5 | Seminis | Fresh Market |
| Everest | White Supersweet | 2 | 3 | Snowy River, Lefroy Valley | Fresh Market |

Diseases are rated 1-5 where:

**1 = Susceptible**
**2 = Moderately susceptible**
**3 = Moderate**
**4 = Moderately tolerant**
**5 = Tolerant**

**na = not available**

**Table 3 and Key adapted from varietal information data sheets from Lefroy Valley Seed Co., Sunland Seeds and Seminis Vegetable Seeds.**

### *Conclusion*

The survey provided a snapshot of pest and disease management practices as well as some additional information on general cultural practices, some statistical information and important information sources for growers. Additionally, the information was gathered from a significant section of the industry ranging over a broad area of Australia. While this report concentrated on diseases and their severity, additional information gathered will be of use in formulating strategies for the conduct of the remaining period of the project.

The survey has shown that while there are a significant number of diseases which growers need to contend with across Australia, the range of strategies they employ to manage the risk posed by these diseases is generally very effective. Monitoring crops, selecting varieties with appropriate resistances, scheduling less resistant varieties at times when environmental conditions are less favourable for disease development and applying fungicides, if necessary, at critical times and appropriate frequencies all contribute to managing the risk of crop damage and consequent reduced productivity.

What also appears obvious is the range of germplasm utilized tends to favour production in the more temperate regions, while the sub-tropical to tropical environments require more intensive management as a result of the limited range of germplasm with tropical adaptability. The industry in Queensland, while only extending northwards into the dry tropical zone, is very deficient in adaptable material to extend the industry further north onto the Atherton Tableland, a fertile, irrigated expanse of productive soils which will come under stronger demand in the future, given the scant water availability in some of our southern production areas.

# Appendix 2. – Milestone #4 Report - Improved IPM Systems in the Australian Sweet Corn Industry

**Improved IPM Systems in the Australian Sweet Corn Industry**

**(HAL Project VG05035)**

**Report: Milestone 4**

**30 May 2007**

**Pests and Beneficial insects and arthropods in Sweet Corn", published and available to the industry**

Contributors:
John Duff[1], Austin McLennan[1],
Adelle Dunn[2], Tony Napier[2], Dr Sandra McDougall[2],
Sonya Broughton[3]
Peter Deuter[1], Carolyn Church[1], Siva Subramanian[4]
[1]QLD DPI&F Gatton Research Station,
[2]NSW DPI, Yanco Agricultural Institute, Yanco NSW 2703
[3]Western Australia Department of Agriculture
[4]QLD DPI&F Bowen Research Station

## Pests and Beneficial insects and arthropods in Sweet Corn

### *Summary*

A wide range of insect pest species have been observed in sweet corn crops grown for the fresh market and processing industry throughout the Australian growing regions. The most commonly seen beneficial insects included predatory thrips, red and blue beetles, pirate bugs, spiders, ladybird beetles and evidence of parasitic wasps.

Helicoverpa (*Helicoverpa armigera*) is generally observed in larger numbers during the final growth stages of the crop (tasselling and silking stages) than in the earlier growth stages (seedling and vegetative stages). The numbers of helicoverpa larvae in most crops are high enough to cause a yield loss if not managed correctly.

Other secondary pests including aphids, mites and thrips occur in most regions but not always in large enough numbers to cause an economic yield reduction.

### *Introduction*

The Australian sweet corn industry has widely adopted Integrated Pest Management (IPM) systems for managing helicoverpa, the main pest. Due largely to the availability of narrow spectrum insecticides for the management of helicoverpa, a range of secondary pests (aphids, mites and thrips) have now become significant insect pests in the sweet corn industry. Previously these pests were controlled by the broad spectrum insecticides applied for helicoverpa control.

Some of these so-called ‘secondary’ pests of sweet corn have yield reducing effects and others are contaminants in the product destined for both domestic and export markets.

The need to manage secondary pests whilst maintaining and/or improving the management of helicoverpa is now seen as a priority for the sweet corn industry. To help develop improved IPM programs, a better understanding of any beneficial organisms which can contribute to the management of the wider range of insect pests in sweet corn is required.

Queensland Department of Primary Industries and Fisheries, New South Wales Department of Primary Industries (NSW DPI) and the Department of Agriculture and Food Western Australia have been involved in helping further improve the IPM strategies developed as part of the sweet corn project VG97036 “Insect pest management in sweet corn” (1997-2001). During the course of this current research, since early 2006 a number of commercial sweet corn fields in QLD, NSW and WA have been scouted for insect pests and beneficials.

This report is a summary of data collected from across Australia encompassing both VG97036 and VG05035.

## Insect pests of sweet corn

Insect pest infestations are a major cause of reduced yield and quality in sweet corn. Monitoring for insect pests and managing them is critical to your success as a sweet corn grower. The main problem is helicoverpa, but other caterpillar pests such as armyworm, yellow peach moth and sorghum head caterpillar can also cause significant damage and yield reduction. Pests such as aphids, thrips, green vegetable bug, dried fruit beetle, soil dwelling insects and the 2-spotted mite can also be problems at different times of the growing season or in different districts.

Since the start of Integrated Pest Management research on sweet corn in 1997, over 20 potential insect and arthropod pests have been identified throughout the major sweet corn growing regions of Australia. Together, these pests can damage the leaves, tassels, silks and cobs of the sweet corn plant to varying degrees, some being more important to the grower than others.

**Soil dwelling pests**

- Cutworm
- African black beetle
- Crickets
- Earwigs
- Wireworms and false wireworms
- White grubs
- Sod webworm

**Pests of cobs and leaves**

- Helicoverpa (*Helicoverpa armigera* and *H. punctigera*)
- Armyworms
- Aphids
- Thrips
- Mites
- Maize leafhopper and other leafhoppers
- Sorghum head caterpillar

- Yellow peach moth
- Green vegetable bug
- Dried fruit beetle
- Red shouldered leaf beetle (*Monolepta* sp.)
- Brown flea beetle
- Rutherglen bug
- Green and brown mirids

### Soil dwelling pests

## Cutworm

Several *Agrotis* species are minor sporadic pests during the establishment of the crop as they cut off young plants at or near ground level. The female moths lay their eggs on soil underneath the leaves of broadleaf weeds and cutworm larvae need to grow to a large size before they start severing young corn plants. For this reason, highest risk is in weedy crops or crop edges with weed hosts nearby, from which grown larvae may migrate seeking food.

#### *Monitoring*

It is usually necessary to dig in the soil to find the cutworm caterpillars to determine the extent of the infestation. Inspecting the crop twice weekly at the seedling and early vegetative stages will indicate whether there is a rapidly increasing proportion of crop damage that warrants management action.

#### *Management of cutworms*

Effective weed management in and around the crop is the most effective measure for preventing cutworm damage. If damage is detected, insecticide treatment of infested patches can provide effective control.

## African black beetle

Both the adults and larvae of the African black beetle *Heteronychus arator* eat emerging shoots or chew into the corn plant stems 5 to 10 cm below ground level, eventually causing them to collapse and die. Infestations can arise from migration of adults from breeding areas in nearby pastures or as a result of planting into ill-prepared land, formerly covered with pasture. The adults are more likely to be causing the damage than the larval stages.

The beetle is glossy black and about 16 mm long and sluggish in its movements. It spends most of its time on and in the soil. The larva, a typical 'C' shaped white grub, grows to 25 mm long, lives in the soil and feeds on grass roots and organic matter.

#### *Monitoring*

Dig around the crop for larvae and adults. Grass pastures are most likely infested with African black beetles. Pitfall traps or sharp sided furrows can also be used to indicate pest presence. Invasions of flying beetles can be assessed by light traps or noting presence of insects around lights.

#### *Management*

Early detection of beetles allows early land preparation to remove pasture host plants, helping to disinfest the area before planting. There are no insecticides registered specifically for control of African black beetle in sweet corn.

## Crickets

Crickets, including the black field cricket *Teleogryllus commodus,* are minor and infrequent pests of sweet corn. Crickets feed at night and hide in the soil by day. They attack the newly planted seed and emerging seedlings by cutting off the tops and leaving them lying on the soil.

The field cricket is about 25 mm long and dark brown or black. Adults are winged and have strongly developed hind legs for jumping. Their presence is indicated by the noise the males make at night by rubbing their forewings.

### *Monitoring*

Listen at dusk for cricket calls. They are often most abundant in March.

### *Management*

Keep soil sufficiently irrigated to prevent excessive cracking which gives crickets easier access to exposed roots. Biological control agents such as diseases, parasitoids, predatory birds and insects appear to have little effect on reducing cricket numbers.

## Earwigs

Black field earwigs, *Nala lividipes,* are minor and infrequent pests of sweet corn. .They usually feed on decaying stubble but also eat newly sown and germinating seed and the roots of crops. Feeding on prop roots may cause the plants to fall over as they grow. The damage is often first noticed when cultivating for weeds because the plants fall over as the equipment passes.
Be aware that not all earwigs are pests – there is a larger brown predatory earwig species often detected in sweet corn and other crops.

### *Monitoring*

Take 300 mm X 300 mm soil samples down to the moist soil layer. The soil should be shaken onto a white sheet and if more than one earwig is found in 20 samples, take management action.

### *Management of earwigs*

Black field earwig is a pest mainly in areas with heavy, black soils. They prefer cultivated soils to zero till. Use press wheels at planting to firm the soil around the seed.  Prepare ground so that germination is as even and rapid as possible.

## Wireworms and False wireworms

Wireworms are the juvenile stage of the click beetle *Agrypnus variabilis,* and grow to about 20 mm long. False wireworms are the larvae of beetle species *Gonocephalum* spp. and *Pterohelaeus* spp. At up to 20-50 mm long, these are typically larger than true wireworm larvae.

The larvae of these pests are elongate, segmented, smooth, shiny and yellow to reddish brown. They are active in the root zone of seedlings in warm conditions, but in hot weather move deeper into the soil.

Larvae of both false and true wireworms tunnel into germinating seeds and attack the roots and shoots of seedlings. They can also bore into the base of corn plants below the ground and burrow up into the stalks. Damaged seedlings wilt and usually die or are stunted and deformed.

Adult wireworms (the beetle stage) are not pests, but adults of false wireworms can attack seedlings at and above ground level, ring barking or completely cutting the stem.

In these ways, wireworm and false wireworm damage can reduce the uniformity of plant stands.

As with other soil dwelling pests, infestations are usually minor and sporadic. However wireworms can be a more serious pest in ground following grass pastures and grains in lightly cultivated soil. Usually by the time the problem is identified the damage is done. In susceptible areas inspect the ground before planting the corn.

### *Management*

Pre-planting treatment, treating seed and good soil preparation can minimise the impact of these pests. They are difficult to manage once corn is planted. Ants and ground beetles are natural enemies of true and false wireworms.

## White grubs

Another sporadic pest, white grub is the name given to the larvae of several scarab beetle species, including Christmas beetles and other related species that are commonly attracted to lights around spring/summer.

Most of the troublesome species have a two-year life cycle. Eggs are laid in the soil in spring and early summer. By the following winter, grubs have passed through two of their three larval growth stages and move downward through the soil - sometimes to a depth of a couple of metres. During these stages they feed on soil organic matter.

As these larvae moult into their third, final and most damaging larval stage, they require living plant tissue so they rise to the root zone where they can cause serious root damage, usually in the spring. Affected plants turn yellow, stop growing, wilt and die; they can easily be pulled out of the soil because no roots remain to anchor them.

The grubs are white with a brown head, ‘C’ shaped and have three pairs of well developed legs. When fully grown they are about 50 mm long. Following rains in October-November, beetles emerge from over wintering pupae in the ground. After mating, the females are attracted to friable soil with high levels of organic matter in which they lay their eggs.

Species include: *Anoplognathus porosus*, *Lepidiota* spp., *Rhopaea magnicornis*, *Antitrogus mussoni*, *Repsimus aeneus*.

### *Management of whitegrubs*

Thorough pre-plant cultivation exposes grubs to birds and mechanically injures them so they die. Pre-plant incorporation of an appropriate registered insecticide is another option for managing this pest. White grubs are difficult to manage once the crop is planted. Fungal diseases such as *Metarhizium anisopliae* and *Beauveria bassiana* can occasionally exert significant control of white grub populations within the soil.

## Sod webworm

The sod webworm *Herpetogramma licarsisalis,* a pest of pasture and lawn grasses, was recently recorded for the first time as a pest of sweet corn in north Queensland in the Bowen region (Figure 1 below). Sod webworm larvae only feed on grasses and live in tubular silk shelters on the surface of the soil. They have been found feeding on the base of the sweet corn seedlings, causing them to fall over in a similar way to cutworm damage.

Figure 1. Sod webworm larva and related damage to sweet corn seedlings

### *Monitoring*

Inspecting the crop twice weekly at the seedling and early vegetative stages will indicate whether there is a rapidly increasing proportion of crop damage that warrants management action.

### *Management*

Effective management of grass weed and pasture species, both in and around the crop, is the most effective measure for preventing sod webworm damage. If damage is detected, insecticide treatment of infested patches should provide effective control.

## Pests of cobs and leaves

### *Helicoverpa*

Helicoverpa is still the major insect pest of sweet corn. There are two species of moths commonly referred to as helicoverpa: *Helicoverpa armigera* and *H. punctigera.* In eastern Australia, the majority of the larvae found in sweet corn are *H. armigera*, also known as the corn earworm or tomato grub. However, *H. punctigera*, or the native budworm, is the dominant species found in Western Australian sweet corn.

Helicoverpa will be present throughout the year, though they are more prevalent in warmer months and less common in cold areas in winter. The moths can travel over long distances between and within regions.

Moths will lay eggs on all parts of the sweet corn plant, but eggs are most abundant in the crop during silking when they are generally laid singly on the silks. The dome shaped eggs are about 0.4 mm in diameter, with ribs down the sides. They are white when freshly laid. As the eggs age they turn from white to cream, then develop a brown ring, which is the caterpillar developing inside. If the eggs turn black instead of brown, they have been parasitised by a beneficial wasp, most likely *Trichogramma pretiosum.* The black colour is the parasitic wasp developing inside. Helicoverpa eggs take two to four days to hatch in warm weather or up to ten days in cool conditions.

Caterpillars (larvae) go through six development stages. This takes about two to three weeks in summer, increasing to four to six weeks as conditions cool. Newly hatched caterpillars are less than 3 mm long and have a dark head and fine dark hairs along the body. Stripes appear on larger caterpillars whose colour varies from green to orange to brown. At the last development stage, helicoverpa caterpillars are 30 to 40 mm long.

When the caterpillar has grown and is fully fed it moves from the plant to the soil. The caterpillar digs into the soil, makes a pupal chamber and an emergence tunnel and then turns into a pupa.

Under normal conditions the pupa will form an adult moth and emerge from the soil after at least 16 days. However, from early-mid autumn the helicoverpa pupa can enter a pupal resting stage known as over-wintering, or diapause. An over-wintering pupa stays in the soil in a state of suspended development for several months before emerging as a moth. Decreasing day length (generally less than 12 hours) and low temperatures, less than about 23°C, trigger over-wintering. In south Queensland it usually begins in mid-March.

The percentage of the population that enters diapause increases with latitude, ranging from very low in north Queensland to very high, probably 100%, in southern production areas. Over-wintering pupae resume development in response to increasing temperatures during late winter and early spring. Seasonal conditions determine the exact timing of moth emergence. Under normal conditions peak moth activity occurs during October. In a warm year, moth emergence will occur slightly earlier while in a cooler year emergence will be delayed. Factors affecting soil temperature also influence moth emergence times. For example plant cover, such as weeds, may lower soil temperature and delay moth emergence.

Helicoverpa caterpillars chew leaves or tunnel down the silk channel of the cob. In the cob they feed on the kernels, and larger larvae do more damage. The presence of caterpillars and damaged kernels make the cob unfit for fresh market (whole cob) sale. Damage can be removed by topping and tailing the cobs and marketing them in pre-packs.

### *Monitoring*

Monitor crops frequently enough to make timely management decisions. This should be at least once per week up until tasselling, then twice per week from tasselling to harvest. It is critical that you monitor your crop from the late vegetative stage.

During the vegetative stage check the leaves, whorl and stem. Once silking has commenced, focus on the cob region, including the flag leaf, silks and some tassels. Monitor more frequently during the silking stage because once eggs have hatched the caterpillars quickly move into the cobs where management is difficult.

Pheromone traps provide additional information about helicoverpa pressure by indicating the flight activities of adult male helicoverpa moths. The male is attracted to the synthetic lure which imitates the female's sex pheromone. Pheromone lures are species specific, so a trap with a *Helicoverpa armigera* pheromone should only catch *H. armigera* moths.

Pheromone traps cannot be used to determine whether control measures are necessary, as research has shown no relationship between trap catches and in-crop helicoverpa numbers. However, pheromone traps can serve as an early warning system for moth emergence from diapause or the arrival of migratory moths, and so indicate when to start checking the crop for eggs and young caterpillars. Inspect the traps every day or two and record the number of helicoverpa moths caught. Comparing yearly catches to the previous season may indicate whether there is likely to be more or less pressure.

### *Management of Helicoverpa*

helicoverpa management will influence the management of many other pests. Biological control, chemical pesticides or a combination of these methods can keep helicoverpa below damaging levels. While biological agents may help in the management of helicoverpa, at certain times of the year pesticides are usually needed to attain a commercially acceptable standard of produce, especially for fresh market sale.

Many parasites and predators attack helicoverpa eggs and caterpillars. However they do not normally provide sufficient management where broad spectrum pesticides are used, or during unfavourable conditions, for example spring time in Queensland's Lockyer Valley when natural enemy numbers are low and only starting to build up with the return of warmer weather.

Good helicoverpa management has been achieved without using pesticides during silking in systems growing regions where:

1. biological pesticides are used;
2. parasites and predators have become established.

This scenario has been achieved by some growers in summer/autumn sweet corn crops in the Lockyer Valley.

## *Armyworms*

There are several armyworm species that may attack sweet corn, and they are difficult to distinguish from each other in the field. This is especially so when the caterpillars are small. Armyworms are sporadic pests and do not always cause economic damage. They include the common armyworm, *Mythimna convecta*, northern armyworm, *M. separata* and the day feeding armyworm, *Spodoptera exempta*.

Armyworm caterpillars can be confused with helicoverpa. Large caterpillars both have green and brown stripes, however large armyworm caterpillars appear smooth with fewer hairs than helicoverpa. The common armyworm caterpillar is brown with dashed black stripes along the back and two wide pale stripes along the sides. The two back stripes continue towards the head as white lines bordered with black, and they continue as black stripes over the head capsule. The head itself is stippled in black and brown. It hides by day and feeds at night. Caterpillars lodge in the whorl where they feed on the new leaves. Older caterpillars are voracious feeders - As the crop develops they will attack silks and developing ears.

Common armyworm and northern armyworm caterpillars hatch from eggs laid in crevices, for example under the sheathing at the base of leaves. Caterpillars undergo a series of moults before reaching full size. When mature, the armyworm caterpillars burrow into the soil to form pupae from which adult moths emerge. The moths are active at night. The life cycle can range from six weeks to several months depending on temperature.

Day feeding armyworm is important at times in northern Queensland where it occurs between late December and March. Outbreaks follow good rains after a drought period and appear to be more serious when the rains are late. Eggs are laid in clusters of a few to about 400 eggs by night flying moths. The clusters are covered with the fawn coloured hairs of the abdomen of the female and are normally found on the leaves of the young plants. Eggs hatch in about three days and the dark, striped caterpillars take about three weeks to mature. Leaves up to 450 mm from the ground are stripped. Damage to crops may not be noticed until the caterpillars are almost full-grown.

### *Monitoring*

Armyworms are common in the vegetative stages of sweet corn, particularly in the whorl and then the tassel as the crop matures. Some feed at night, making it difficult to identify the cause of the leaf damage and to monitor. Damage may not be noticed until the grubs are fully grown, when they may be difficult to kill. Feeding on silks may affect kernel set and detract from the appearance of fresh market cobs

### *Management of armyworms*

Armyworms are rarely in sufficient numbers to warrant management action. However as a caterpillar pest, their management is similar to helicoverpa. They are, however, more likely to be killed by older pesticide chemistries as armyworms do not have tolerance to pesticides.

Parasitic wasps (Figure 2) and insect diseases (naturally occurring or via a commercial formulation) can play a significant role in armyworm management, often before the critical reproductive stage of the crop is reached. Armyworm caterpillars are subject to a range of fungal and viral disease, however these normally become widespread only when large populations of caterpillars occur and they act too late to prevent serious damage by the pest. The virus which attacks armyworm species is different from the commercially available NPV (or nucleopolyhedorvirus) which only kills helicoverpa larvae. However less specific *Bt* formulations based on the bacterium *Bacillus thuringiensis* will kill armyworms. The parasitic wasps *Cotesia* spp. can give significant control of armyworms in environments with low insecticide use.

Figure 2. *Cotesia* sp. larvae emerging from parasitised armyworm larvae.

## *Aphids*

The corn aphid *Rhopalosiphum maidis* is the most common aphid in sweet corn, although the green peach aphid *Myzus persicae* can also be found attacking sweet corn. Aphids in sweet corn can spread Johnson grass mosaic virus.

In sufficient numbers, aphids can damage plants by sucking sap causing wilting and leaf puckering. Their excreted honeydew is sticky and hard to remove, and a black sooty mould grows on it, making cobs unattractive and unsaleable.

### *Monitoring*

Monitor crops to ensure that aphids do not build up to levels that will cause economic damage. They first appear on the underside of lower leaves in the vegetative stage of the plant. Adults also fly into the whorl and spread through the top of the plant. Take action during this stage if there are high numbers. When aphids are in the cob wrapper leaves they are difficult to manage and it is usually too late.

When monitoring, especially during the vegetative stage, assess the activity of beneficials that attack aphids such as ladybirds, lacewings or parasitic wasps.

### *Management of aphids*

Effective aphid management includes good farm hygiene, beneficial insects and insecticides. Natural predators of aphids include ladybird (Coccinellid) beetles and their larvae, and hover fly and lacewing larvae. Several species of parasitic wasps lay their eggs in aphids. A wasp larva develops within each aphid which dries and becomes swollen, tan/brown and mummified. An adult wasp emerges from the aphid mummy.

Beneficials can be effective in managing aphids, unless aphid numbers build up to high levels before the beneficials gain control. Minimise the use of broad spectrum pesticides to achieve the most effective biological control.

## *Maize leafhopper and other leafhoppers*

A number of leafhopper species are found in sweet corn.  The maize leafhopper *Cicadulina bimaculata* is the most common leafhopper, with the vegetable leafhopper *Austroasca viridigrisea* and the common brown leafhopper *Orosius argentatus* also found on sweet corn from time to time.  Leafhoppers feed by sucking sap from the leaves and are generally found on the underneath side of the leaves. In susceptible varieties, the disorder wallaby ear occurs when heavy infestations of more than 15 leafhoppers per plant inject a toxin into the plant while feeding, which causes a growth deformity in the emerging leaves.

The most significant damage done to sweet corn by leafhoppers is through wallaby ear rather than direct feeding.

### *Monitoring*

Monitor crops carefully to ensure leafhopper numbers are not building up quickly.

### *Management of maize leafhopper*

An IPM approach, including planting wallaby ear resistant varieties, farm hygiene and the use of pesticides when necessary, is the best way to manage maize leafhoppers.

## *Thrips*

A number of thrips have been identified from sweet corn including maize thrips *Frankliniella williamsi*, tomato thrips *Frankliniella schultzei*, western flower thrips *F. occidentalis*, onion thrips *Thrips tabaci*, plague thrips *T. imaginis* and a black plague thrips *Haplothrips froggatti*. Maize thrips is the most damaging of all the thrips (Figure 3) and the most common across regions with the other thrips occurring in either the tassels or silks to varying degrees.

Thrips damage sweet corn by rasping plant tissue in the whorl, under the leaf sheath or wrapper leaves or on the silks. They are rarely an economic problem through direct feeding, however damage to seedlings can be a problem in vegetative crops when large numbers cause a streaking of the young leaves.

Thrips can also be a costly contaminant in cobs destined for the export market, which has a zero tolerance for live insects.  The *Haplothrips* species (Figure 4) has been found in silks during the spring but it is unclear what, if any, damage it may be causing there.

Figure 3. Damage caused by *Frankliniella williamsi* to the whorls of young sweet corn plants.

Figure 4. *Haplothrips froggatti* which can be found amongst sweet corn silks during spring plantings.

### *Monitoring*

Thrips are present throughout the life of the crop, however their presence is most significant during cob development when they become contaminants. Monitoring the whorl cob region before silk expression will provide an indicator to whether action is necessary. Vigilant monitoring is important as it is highly likely that the crop will be reinfested by thrips carried on the wind.

### *Management of thrips*

Destroy old crops and weeds in and around the block.

Predatory bugs, especially pirate bugs (*Orius* sp.) can play a major role in managing thrips. However natural populations of these bugs do not decrease the population enough to reduce cob contamination so a combination of management options may be needed.

## *Mites*

The two-spotted mite *Tetranychus urticae* is usually more of a problem in warm dry conditions and are known to infest a wide range of plants. All active stages cause a yellow stippling of the upper surface of the leaf and fine webbing underneath. They can be spread by wind, and carried on clothing, machinery, birds and insects. Mites also make some workers itchy.

### *Monitoring*

Monitor for mites by looking for the yellow stippling on the upper surface of leaves and checking the under surface for mites and their webbing. They will often be near the main rib. A hand lens will help to see the mites more clearly. Mite infestations typically begin in the lower leaves of the crop, so the presence of mites in leaves higher in the canopy is a sign that an infestation is building.

### *Management of mites*

Mites can be very difficult to manage in warm, dry conditions as their populations can rapidly increase, doubling within a very short time. Monitor the crop and take action as early as possible to prevent a major flare up of mites. Hygiene, predators and miticides (where registered) are all options that should be considered.

Cleaning up old crops immediately after harvest and removing weeds and volunteer hosts from around the crop will help to reduce initial mite populations.

Predatory mites (*Phytoseiulus persimilis*) can be purchased to manage spider mites, however many of the chemical pesticides used to manage other pests will also kill these predators. The companies supplying predatory mites will supply a list of chemicals that are least harmful to the predators. Releasing predatory mites into the headlands around new plantings may help reduce mite numbers before they move into the crop.

Some other natural predators are often detected in sweet corn crops —lacewing larvae, predatory thrips and the adults and larvae of the very small ladybird *Stethorus* spp. (Figure 5), Sprays for other pests that inadvertently kill or disrupt these and other mite predators can result in a rapid flaring of mite populations and the need for a miticide application.

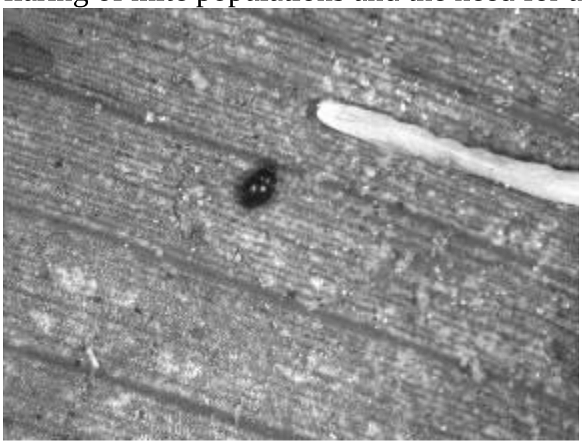


Figure 5. Adult *Stethorus* beetle feeding on mite colony on sweet corn leaf.

## Sorghum head caterpillar

*Cryptoblabes adoceta* larvae can chew leaves as well as be contaminants in the silk and wrapper leaves of cobs.

### *Monitoring*

Early stages in the life cycle are difficult to see, so start monitoring for this pest as silking begins. Look in the cob region, especially the wrapper leaves and the silks. Lift up and look under the silks where they are sticking to the outer wrapper leaves. More than one caterpillar may be found on an infested cob.

Sorghum head caterpillar is also a pest of field crops (sorghum), so neighbouring crops may be a source of infestation and indicate an increased risk.

### *Management*

There have been reports of trichogramma parasitising the eggs. A parasitic wasp *Cotesia* sp. also attacks the caterpillars. Evidence of this wasp's activity is a white cocoon seen beside a dead grub on the cob wrapper leaves.

Spraying is rarely recommended specifically for sorghum head caterpillar as they are also incidentally controlled by some narrow-spectrum insecticides applied for helicoverpa.

## *Yellow peach moth*

Yellow peach moth *Conogethes punctiferalis* is a caterpillar pest of sweet corn in Queensland. Caterpillars tunnel into stems and the side of cobs damaging the kernels. It tends to be a minor pest but can cause economic damage. Where a yellow peach moth larva has tunnelled into a cob, that cob will be unsaleable unless cut and sold as pre-packaged portions.

### *Monitoring*

It is difficult to find the eggs and young caterpillars of this pest but monitoring should target the silking period and continue until close to harvest. Caterpillars are often found in the cobs but are also found between the cob and the plant stem. Frass and webbing may be found around the entrance hole.

### *Management*

There have been reports of trichogramma parasitising the eggs of yellow peach moth. A tachinid fly parasitoid has also been observed as a natural enemy in some situations. The use of soft option pesticides should be encouraged as the older broad spectrum insecticides will disrupt natural enemy activity.

## *Green vegetable bug*

The green vegetable bug *Nezara viridula* is a sporadic pest of sweet corn. It is more likely to be prevalent when alternative host crops such as soybeans are present in the vicinity of the sweet corn crop. The bugs usually appear late in the crop during cob formation.

Adults and nymphs will damage kernels by sucking the contents. The insertion point for the mouth parts also provides access for secondary disease infections and rots that affect the cob.

### *Management*

The only effective insecticides for green vegetable bug are broad-spectrum, so treating will kill many of the natural enemies in the crop that are providing biological control of helicoverpa. Consider the pest management strategy for the whole crop before making any decision to spray. Weigh up the loss to green vegetable bug damage versus potential loss to helicoverpa if a helicoverpa management system based around biological control is disrupted.

The parasites of green vegetable bug include several egg parasitoids, with *Trissolcus basalis* being the most common. There is also a fly, *Trichopoda giacomellii*, that parasitises adult green vegetable bugs – *Trichopoda*'s white eggs are clearly visible where they have been laid on the back of a parasitised bug (Figure 6).

These natural enemies have a more significant impact in reducing the overall size of the pest population than in rapidly reducing numbers once green vegetable bug is present in the crop at damaging levels.

Figure 6. Trichopoda fly (inset) and green vegetable bug adult, showing a Trichopoda egg laid near its head.

## *Dried fruit beetle*

Dried fruit beetles *Carpophilus* spp. are especially evident after pollen starts to shed. They are often found around the leaf sheaths where pollen settles, and then in the silks and developing cob. If harvesting is delayed the beetles enter the cobs, damaging kernels and contaminating the cob. Beetles are also attracted to fermenting cobs where caterpillars have caused some damage and moisture has entered the damage site.

Timely harvest usually avoids beetles being a problem as a contaminant. Management is not usually necessary.

## *Redshouldered (Monolepta) leaf beetle*

Adult red shouldered leaf beetles, *Monolepta australis*, move into the crop in swarms from spring to autumn and eat the leaves. They also chew on emerging silks which may affect pollination.
If crops are monitored regularly, spot spraying of the swarms with an appropriate chemical should be enough to manage this pest. Swarms often follow spring-summer rainfall events.

## *Brown flea beetle*

These small shiny brown flea beetles *Chaetocnema* spp. (Figure 7) are about 2mm long with the last pair of legs having an enlarged segment for jumping. They have been found attacking the leaves of sweet corn causing small holes in the leaves and can be found in the crop from the seedling stage up until harvest. They do not seem to be affecting yield and are only considered a minor pest. They have only recently been seen in sweet corn, possibly as a result of the dry conditions leading to reduced food plant availability, thus concentrating them in available crops.

The flea beetle is not considered sufficiently damaging to warrant control. Extreme numbers would have to be present in the early vegetative stages of the crop to justify any concern.

Figure 7. Small brown flea beetle can be found

on a wide range of crops including sweet corn.

## ***Rutherglen bug***

Adult Rutherglen bugs *Nysius vinitor* are about 5mm long, typically grey-brown-black in colour and very mobile. Their wings are clear and folded flat on their back. They can be found on most plant parts throughout the growing season, usually in small numbers.

They are not considered a pest of sweet corn but could be a contamination issue at harvest. Management may only be necessary if sufficiently large numbers are going to cause a contamination issue, especially if the crop is destined for the export market.

Decisions to apply late insecticide treatments for removing contaminant insects must always take into account insecticide withholding periods.

## ***Green and brown mirid***

The green mirid *Creontiades dilutus* and the brown mirid *C. pacificus* are similar in appearance. Adults are 7-8mm long, slender insects with long legs and antennae. As the names indicate, the green mirid is pale green in colour, while the brown mirid is green with brown markings on the legs, antennae and just behind the head and on the wings. The immature stages of both species can also be distinguished by their antennae – Brown mirids have red-brown bands on their antennae, while green mirid nymphs have uniformly green antennae with no bands.
Mirids feed by piercing plant tissues with their mouth part, eventually destroying the cells in the area of feeding.
Damage from these insect pests has not been reported in sweet corn and it is possible that they are only being seen in this crop due to weeds either in or close by to the crop. Nearby crop hosts such as beans may also be a source of mirids. Management is not considered necessary if you see this insect in sweet corn.

Table 1 - Scouting results; insect species found present during crop scouting from 1997 to 2007.

| **Common name** | **Scientific name** | **Where insect is found on the plant** | **Importance** | **Frequency** |
|---|---|---|---|---|
| African black beetle | *Heteronychus arator* | In soil around young plants | minor | infrequent |
| Cut worms | *Agrotis spp* | In soil around collapsed plants | minor | infrequent |
| Crickets | *Teleogryllus commodus* | In soil around plants | minor | infrequent |
| Black field earwigs | *Nala lividipes* | In soil around plants | minor | infrequent |
| Wireworms | *Agrypnus spp. and Gonocephalum spp.* | In soil around collapsed plants | minor | infrequent |
| White grubs | *Anoplognathus porosus, Lepidiota spp., Rhopaea magnicornis, Antitrogus mussoni, Repsimus aeneus* | In soil around plants | minor | infrequent |
| Sod webworm | *Herpetogramma licarsisalis* | Seedlings near base of plant | minor | infrequent |
| Dried fruit beetle | *Carpophilus spp* | Silks and tip of cob, and leaf axils | moderate | regular |
| Brown flea beetle | *Chaetocnema sp.* | Leaves | minor | regular |
| Minute brown scavenger beetles | *Lathridiidae* | Most parts of plant | minor | infrequent |
| Red-shouldered leaf beetle | *Monolepta australis* | Leaves | minor | infrequent |
| Green leafhopper | *Austroasca viridigrisea* | Underside of leaves | minor | infrequent |
| Maize Leafhopper (pale brown leaf hopper) | *Cicadulina bimaculata* | Underside of leaves | moderate | regular |
| Green Mirid | *Creontiades dilutus* | Leaves, silks | minor | infrequent |
| Green peach aphid | *Myzus persicae* | Underside of leaves, whorls, tassels, cobs | moderate | infrequent |
| Green vegetable bug | *Nezara viridula* | Leaves, cobs | minor | infrequent |
| Rutherglen bug | *Nysius vinitor* | Most parts of plant | minor | infrequent |
| Common brown leafhopper | *Orosius argentatus* | Underside of leaves | minor | infrequent |
| Maize Aphid | *Rhopalosiphum maidis* | Underside of leaves, whorls, tassels, cobs | major | regular |
| Yellow peach moth | *Conogethes punctiferalis* | Bore into side of cobs | moderate | regular |
| Sorghum head caterpillar | *Cryptoblabes adoceta* | Beneath old silks | moderate | regular |
| Corn earworm/helicoverpa | *Helicoverpa armigera* | Whorls, tassels, silks, cobs | major | regular |
| Native budworm | *Helicoverpa punctigera* | Whorls, tassels, silks, cobs | moderate | infrequent |
| Armyworm | *Mythimna convecta* | Whorls and tassels | moderate | regular |
| Armyworm | *Mythimna spp* | Whorls and tassels | moderate | regular |
| Plague thrips | *Thrips imagines* | Most of the plant | minor | infrequent |
| Onion thrips | *Thrips tabaci* | Most of the plant | minor | infrequent |
| Western flower thrips | *Frankliniella occidentalis* | Most of the plant | minor | infrequent |
| Tomato thrips | *Frankliniella schultzei* | Most of the plant | minor | infrequent |
| Maize thrips | *Frankliniella williamsi* | Whorls, silks, cob | moderate | regular |
| Black plague thrips | *Haplothrips spp.* | Tassels and silks | minor | infrequent |
| Two spotted mite | *Tetranychus urticae* | Underside of leaves | moderate | regular |

## Beneficial insects in sweet corn

Not all the insects we see in sweet corn are doing damage to the crop. Many are in fact beneficials, or 'natural enemies' of the real pests. It is important to be able to recognise friend from foe, and take the appropriate steps to make the best use of these beneficials.

Not all natural enemies are insects. Other non-insect arthropods that help control pests in your crop are spiders and predatory mites. Avoiding the use of broad spectrum pesticides, using biological pesticides such as *Bacillus thuringiensis* (Bt) or helicoverpa nucleopolyhedorvirus (NPV) and introducing natural enemies into the crop all increase natural enemy activity.

Rarely do natural enemies alone achieve a standard of pest management sufficient to meet quality requirements for marketable produce. Therefore their role should be considered as part of an IPM system.

Beneficial insects fall into two groups – parasitoids and predators.

# Parasitoids

Parasitoids are organisms that parasitise and kill their hosts. The adults are free-living and are usually wasps or flies. The adult lays its eggs within or on the host pest at a critical like stage. The immature stage develops on or within an insect host, completing their entire development within that host by consuming it and eventually killing the host. Parasitoids tend to be very specific to their host, there are various wasp parasitoids that attack moth eggs, aphids or caterpillars.

Egg parasitoids, such as *Trichogramma* spp. and *Telenomus* spp. may attack and develop in a range of moth eggs, typically turning the egg a silvery black. In comparison parasitised caterpillars show few external signs of parasitism before dying. The parasitoid larvae can sometimes be seen if the parasitised caterpillar is carefully pulled apart. Larval parasitoids include *Heteropelma* and several smaller Braconid wasps, *Cotesia*, *Microplitis* and tachinid flies.

Aphids are often parasitised and are noticeable as bloated buff or brown shells commonly called 'mummies'. The aphid parasitoid, a small wasp, emerges through a circular hole in the abdomen of the aphid shell.

To determine the level of parasitoids in your crop you need to collect and rear the pests to observe if parasitoids will emerge from their host. Emergence could take from one to 50 days. Apart from protecting existing parasites in your crop by using chemicals that will not harm beneficials, a limited number of parasitoids are mass reared by commercial producers. The most common is the egg parasitoid *Trichogramma pretiosum* which has a wide host range.

# Predators

Predators feed directly on their prey. They include insects such as predatory beetles, lacewings, predatory bugs, predatory mites and spiders. Most predators are generalists, attacking a wide range of insects such as aphids, thrips, moth eggs, and small, medium and large grubs. Predators generally attack insects that are smaller than themselves.

Predators also supplement their diet with nectar, pollen and fungi. In most cases it is the larvae of these predators that are the main feeders and they tend to feed on the slower moving sap suckers including aphids, whiteflies and mites. Table 2 shows the relationships between natural enemies and pests found in sweet corn.

Table 2 Relationships between natural enemies and primary and secondary insect pests found in sweet corn.

| | Beneficials (natural enemies) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Parasitoids* | | | | | | | *Predators* | | | |
| **Pest** | **Trichogramma** | **Telenomus** | **Microplitis** | **Heteropelma** | **Cotesia** | **Tachinid fly** | **Aphid parasitoid** | **Lacewings** | **Ladybirds** | **Predatory bugs** | **Spiders** |
| Helicoverpa eggs | ✓ | ✓ | | | | | | | ✓ | ✓ | ✓ |
| Helicoverpa larvae | | | ✓ | ✓ | ✓ | ✓ | | | small | ✓ | ✓ |
| Armyworm | | | | | ✓ | | | | | ✓ | |
| Sorghum head caterpillar | | | | | ✓ | | | | | ✓ | ✓ |
| Yellow peach moth | ✓ | | | | | | | | ✓ | | ✓ |
| Aphids | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Thrips | | | | | | | | | some | ✓ | ✓ |

✓ indicates host or prey of natural enemy

## *Enhancing effectiveness of beneficial insects*

The following actions will help increase the effectiveness of beneficials.

1. Monitor crops to help reduce unnecessary insecticide usage;
2. Use pesticides (insecticides, miticides and fungicides) only when necessary;
3. Use an appropriate pesticide to control the insect pest and limit its direct impact on natural enemies (for example NPV sprays);
4. Provide an alternative food source for the adult parasitoids and predators (for example weeds or other flowering plants are a good source of nectar and pollen);
5. Make mass (inundative) releases of commercially reared beneficials, for example egg parasitoids and mite predators, so they become effective more quickly. Inundative releases have variable results. In some areas the introductions did have an effect and reduced damage. Releases over several years may result in establishment of populations of *Trichogramma pretiosum* and predatory mites in some areas.

## Parasitoids in sweet corn

### Egg parasitoids of helicoverpa (Trichogramma and Telenomus)

There are several species of egg parasitoids found in most of Australia’s sweet corn growing regions. The most common egg parasitoid was species is *Trichogramma pretiosum*, and it is reared commercially and available for purchase and release. Depending on the season, other species such as *Trichogrammatoidea* spp. and *Telenomus* spp. also occur in sweet corn crops. The adult wasps are all minute and rarely visible when monitoring crops. However the black parasitised eggs can be spotted easily and percentage parasitism can be readily estimated.

There is little information on the presence of *Trichogramma* sp. and *Telenomus* spp. in Tasmania but they are considered to be either absent or uncommon.

Egg parasitoids can have a significant impact on helicoverpa populations in the absence of synthetic pesticides, largely because they prevent egg hatch of the caterpillar pests attacked.

## Microplitis – larval parasitoid

A parasitoid of helicoverpa and *Spodoptera* spp., *Microplitis* wasps are distinguishable by their brown pupae often found lightly attached to the dying or dead and shrivelled body of its host caterpillar.

The female wasps lay single eggs into young caterpillars. The wasp larva emerges and feed on the caterpillar's internal tissues before emerging from its host to pupate. The wounded caterpillar then dies. *Microplitis* is an important larval parasitoid because parasitised larvae are killed at around 10-14 mm in size, well before they reach their most damaging stage.

Potentially very common on the mainland, especially in crops where broad-spectrum insecticides have been avoided, there is little information on the presence of *Microplitis* in Tasmania but it is considered to be either absent or uncommon.

## Cotesia – larval parasitoid

These parasitic wasps lay eggs into larvae of armyworm, helicoverpa and sorghum head caterpillar. The larvae emerge to pupate, forming a single white pupa (cocoon) or white bundles of pupae on the outside of the caterpillar. The dead caterpillar may still be attached to the pupae.

These larval and aphid parasitoids are often brown or black and very small (<6 mm). They look like flying ants or tiny flies. From side on you can see a restricted 'waist'. Female wasps have a 'sting' at the tip of their abdomen - this is the ovipositor that is used to insert the eggs into the host. Another distinguishing feature is that when they are walking on foliage you can often see their antennae quivering and tapping the foliage as they search for chemical traces left by hosts.

*Cotesia* has been recorded in all Australian growing regions.

## Tachinid flies

These parasitic flies are grey/black and slightly bigger than a house fly. They lay a white oval egg on or near caterpillars. The fly larva enters the caterpillar and attaches to the skin, leaving a breathing hole. The maggot grows inside the caterpillar, eventually killing it. It then forms a brown, oval pupal case from which the fly emerges. Large host caterpillars may have more than one tachinid fly larvae living inside them.

There are several species of tachinid flies that attack moth larvae in Australian sweet corn. Tachinids can play an important role in limiting population growth, but because they typically only kill their larval hosts once the caterpillars have reached full size or pupated, parasitism by tachinids does not reduce the damage caused by larvae already present in the crop.

## Minor larval parasitoids of caterpillar pests

These include parasitoids such as the two-toned caterpillar parasite *Heteropelma scaposum*, orchid dupe *Lissopimpla excelsa* and the orange caterpillar parasite *Netelia producta*. They can generally be seen flying around the crop looking for larvae to lay their eggs into or onto their host. Like *Microplits and Cotesia*, their larvae feed from within their host caterpillars - except for *Netelia*¸ the larvae of which feed externally. But, unlike *Microplitis*¸ these other larval parasitoids are limited in their ability to prevent immediate crop damage because they only cause host death once the caterpillar has finished its feeding and pupated.

## Aphid parasitoids

The presence of these parasitoids is evident by swollen tan coloured dead aphids (mummies) within a colony. The parasitoid lays its eggs into the aphid where the larvae then feeds on the contents of the aphid and eventually pupates within the aphid. The adult parasitoid eventually chews its way out of the mummy towards the rear of the aphid leaving a circular emergence hole.

A number of aphid parasitoids have been found attacking aphid colonies in sweet corn, especially crops where minimal insecticide input has been the norm. In many situations, aphid parasitoids combined with other aphid predators are able to rapidly and substantially reduce aphid pest populations.

# Predators in sweet corn

## Ladybird beetles

Predatory beetles include ladybird beetles, of which several species can be found in unsprayed sweet corn crops. The majority of them are orange or red with a different number and shape of black spots. Their bodies are dome shaped with a hard wing covering. Their eggs and larvae are also prevalent, especially when there are aphids present. Eggs are yellow to orange, oval shaped and are laid upright on leaves, usually in a cluster. Larvae are black with coloured markings on the back. They have three pairs of prominent legs.

Ladybird beetles are very effective predators of aphids but will also eat moth eggs, small larvae thrips and mites. The more common ladybirds include the White collared ladybird beetle, Transverse ladybird beetle, Striped ladybird beetle, Three-banded ladybird beetle and the Mite feeding ladybird beetle (*Stethorus*).

## Pirate bug *(*Orius sp.)

Pirate bugs are black and about 3 mm long. Their wings make a black and white cross pattern on their back. If thrips – a favoured prey item - are present, they are commonly seen where the leaves wrap around the stem or in the silks. The wingless nymphs are orange and black and they go through several stages before becoming adults. Pirate bug eggs are white, oblong and are laid embedded in the leaf, often near the sheath. Pirate bugs are common predators of thrips but also feed on moth eggs, aphids and small caterpillars.

## Black mirid

The black mirid (Figure 8) *Tytthus chinensis* moves faster than pirate bugs and are larger and thinner. They have long antenna and do not have the cross pattern on their back. They are smaller than pest green and brown mirids. Their prey includes moth eggs and soft bodied insects.

Figure 8. Black mirid found in sweet corn.

## Big eyed bug

The big eye bug *Geocoris lubra* is about 4 mm long and is distinguishable by its large protruding black eyes. Its body is also black and squatter in shape than the pirate bug. Its prey includes aphids, mites, young caterpillars and moth eggs.

## Damsel bug

The damsel bug *Nabis kinbergii* is one of the larger predatory bugs found in sweet corn, being up to 8 mm long. It is brown, long and thin, with large eyes and long antenna. Their prey includes soft bodied insects, moth eggs, small larvae and mites.

## Lacewings

Brown and green lacewings are common in unsprayed sweet corn crops. Both adults and larvae of the brown lacewing are predatory, whereas only the larvae of the green lacewing are predatory, especially on aphids. The adult brown lacewing has brown wings. Larvae are also brown and eggs are laid singly on leaves. Green lacewing adults have green wings and are slightly larger than brown lacewings. Their larvae carry debris on their back, unlike the brown lacewing larvae, and their eggs are laid on long slender stalks and usually in small clusters.

## Spiders

Three types of spiders are commonly found in sweet corn crops – web spinners, foliage dwellers and soil dwellers. Wolf spiders are common soil predators, whereas the crab spiders, jumping spiders, orb weavers and many others are active predators in plant canopies. Their impact on pests has not been well documented, however spiders represent up to a third of the predators recorded in sweet corn crops. They eat moth eggs, small caterpillars, aphids and thrips.

## Predatory mites

Various predatory mites can occur naturally in unsprayed crops. *Phytoseiulus persimilis* is a predatory mite that can be bought commercially and released. Given the right environmental conditions it is a very effective predator of two-spotted mite.

The mite is orange and about 1 mm long, larger than a two-spotted mite. Their body is pear shaped, appears smooth and almost dome like. Another distinguishing feature is that predatory mites move faster than two-spotted mites.

## Minor natural enemies

There is a range of minor beneficials belonging to various groups including hover flies, assassin bugs, predatory shield bugs, brown earwigs, predatory ground beetles and Anthicid beetles, pollen beetles (red and blue beetles), pygmy crickets and predatory thrips.  Pollen beetles can be quite common in southern NSW.

## Natural enemy reference tables

The range and effectiveness of beneficials will vary between regions and may change from year to year in each region. The time of year when they are active may also vary. In most areas, trichogramma wasps have far more impact on helicoverpa control in sweet corn than all other beneficials.

Table 3 rates the efficacy of a range of beneficial insects and spiders in sweet corn.

Table 4 shows the impact of insecticides on pests and beneficials.

**Table 3**. The efficacy of a range of beneficial insects and spiders

| Common name | Scientific name | Beneficial rating* |
|---|---|---|
| **Wasps and ants:** | **Hymenoptera:** | **+++++** |
| Trichogramma | Trichogrammatidae | +++++ |
| Black ants | *Iridomyrmex* sp. | ++++ |
| Aphid parasitoids | *Various* | ++++ |
| Microplitis | *Microplitis demolitor* | +++ |
| Telenomus | *Telenomus* spp. | +++ |
| **Bugs:** | **Hemiptera:** | **++++** |
| Black mirid | *Tytthus chinensis* | +++++ |
| Pirate bug | *Orius* sp. | +++++ |
| Apple dimpling bug | Campylomma liebknechti | ++ |
| Brown smudge bug | *Deraeocoris signatus* | ++ |
| Bigeyed bug | *Geocoris lubra* | + |
| Damsel bug | Nabis kinbergii | + |
| **Spiders:** | **Araneae:** | **+++** |
| Foliage dwellers (e.g. jumping spiders) | Salticidae | ++++ |
| Soil dwellers (e.g. wolf spider) | Lycosidae | +++ |
| Web builders (e.g. orb weaver) | Araneidae | ++ |
| **Beetles:** | **Coleoptera:** | **+++** |
| Ladybirds | Coccinellidae | +++ |
| Carab beetle | Carabidae | ++ |
| Red and blue beetle | *Dicranolaius bellulus* | ++ |
| Green soldier beetle | *Chauliognathus pulchellus* | + |
| Brown Anthicid beetles | *Anthicid sp.* | + |
| **Lacewings:** | **Neuroptera:** | **++** |
| Brown lacewing | *Micromus tasmaniae* | ++ |
| Green lacewing | *Mallada* spp. | ++ |
| **Flies:** | **Diptera:** | **++** |
| Tachinid flies | Tachinidae | ++ |
| Hover flies | Syrphidae | + |

*Level of pest management in sweet corn = Low (+); Moderate (+++); High (+++++). Source: DPI note *Helicoverpa in sweet corn*

**Table 4.** Impact of insecticides on natural enemies

| Insecticides | IPM rating[1] | Beneficial insects | | | | | |
|---|---|---|---|---|---|---|---|
| | | Parasitic wasps | | Predators | | | |
| Active ingredient | * = poorest performer<br>**** = best performer | **Egg parasitoid** trichogramma | **Larval parasitoids** | **Predatory beetles** | **Predatory bugs** | **Lacewing** | **Spiders** |
| | | | | | | | |
| Bacillus thuringiensis (Bt) | **** | L | (VL) | VL | VL | (L) | VL |
| carbaryl | ** | H | H | H | H | (M-H) | – |
| endosulfan | *** | H | - | M | M | (M) | M |
| | | | | | | | |
| imidacloprid | ** | (H) | - | H | H | (H) | VL |
| methomyl | * | H | H | VH | H | (H) | M |
| NP virus | **** | VL | VL | VL | VL | VL | VL |
| organophosphates[1] | * | (H) | H | H | H | (H) | H |
| petroleum oil | | | | | | | |
| | | | | | | | |
| propargite | *** | L | L | L | L | L-M | L-M |
| spinosad | *** | (M) | M | L | L | - | L |
| synthetic pyrethroids[2] | * | H | VH | VH | VH | (H) | VH |
| thiodicarb | * | H | - | VH | M | (H) | L |

Prepared by Bronwyn Walsh.
**1** Overall IPM rating: impact on parasitic wasps, predators, spectrum of pests; (% 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%. '–' indicates no data available; '()' estimated toxicity.
Ratings are based on research by Scholz (2001), Wilson, Holloway, Mensah and Murray (2001).

*Disclaimer: Information provided is based on the current best information available from research data.
Users of these products should check the label for further details of rate, pest spectrum, safe handling and application.
Further information on the products can be obtained from the manufacturer.

## Discussion

There are many beneficial insects and spiders that can play an important role in minimising pest numbers and damage to sweet corn.

However, if we want them to be effective, we need to give them the best possible opportunity to persist and thrive in our crops.

For the grower, that means paying careful attention to the pattern of insecticide use in sweet corn:

- For helicoverpa control, only use selective options that have minimal impact on beneficial insects. Many such products are now available, and some of them will also be active against other caterpillar pests in the crop.
- For pests other than helicoverpa, especially sucking pests such as thrips, aphids and green vegetable bug, broad spectrum sprays may be the only available chemical option. In these cases, growers should only target the pests when absolutely necessary, as even one application of a broad spectrum can deplete natural enemy populations, potentially resulting in the resurgence of other pests, including the original target.

To identify those situations where broad spectrum sprays are essential to prevent damage and those where they could perhaps be avoided, growers need to develop confidence in what pest numbers can be tolerated without serious damage.

Regular monitoring of changes in pest numbers is therefore absolutely critical. But what about monitoring of beneficial insects and spiders?

There are several key points to consider.

First, without some direct monitoring, natural enemies will often remain unseen and under-appreciated helpers. Knowing what is there enables growers to base insecticide selection around preserving the key beneficial groups present and active in the crop at that time.

Secondly, it is important to recognise that attempting to rely on biological control will not be practical for every pest. For example, helicoverpa, aphids and mites all have a diverse and well adapted suite of natural enemies that attack them and that are capable of reducing pest numbers in the crop. But there are other pests like green vegetable bug, leafhoppers and many soil pests that, once they are detected at potentially damaging levels, are unlikely to be brought under control by natural enemies.

Finally, not all natural enemies present in crop are equally beneficial. Some, like *Trichogramma pretiosum* - a key natural enemy of helicoverpa in sweet corn – are vital to the success of an IPM approach, and efforts to base insecticide selection around its preservation are well justified. Ladybirds are another effective predator group in sweet corn, particularly against aphids. Since some of the narrow-spectrum helicoverpa products have a greater impact on beetles than other options, this may influence growers' insecticide selection for helicoverpa, based on their assessment of the aphid risk.

But some other natural enemies, while important, kill their prey or host too late in the pest's lifecycle to prevent it from causing crop damage. Examples include many of the caterpillar parasites (wasps and flies) or the *Trichopoda* fly that attacks green vegetable bug adults, which - despite eating many of the bug's internal organs - may not even kill it outright. Natural enemies of this kind are important to preserve because they prevent adults from breeding, but because their impact on pest numbers and damage levels will not be felt until the next generation, in many cases this may be too late.

The key is to know what you have in your crop – pests and beneficials – and what they are capable of, and make decisions accordingly.

**Remaining challenges for biological control in sweet corn**

In general, biological control of helicoverpa in sweet corn is well advanced. This is supported by the availability of several narrow spectrum insecticides and a range of effective natural enemies that attack all its life stages.

But to date there are no highly selective options for many of the sucking and/or minor pests attacking sweet corn. And many of these pests lack the same set of focussed predators and parasitoids that underpin the likelihood of successful biological control. This is a remaining challenge for insect pest management across many crops, not just sweet corn.

The marketing of sweet corn also plays a key role in determining a grower's ability to reduce pesticide inputs - i.e. there is more scope to tolerate some damage in non-whole cob markets, where damage can be physically removed during grading, but less scope in fresh whole-cob markets.

Keeping crops free of all pests through frequent insecticide applications is also rarely possible without introducing long term consequences such as insecticide resistance and overall suppression of beneficial arthropods on the farm. Indeed, it's a fallacy that more spraying necessarily results in less damaged cobs or higher profits. It has often been observed that the need for helicoverpa sprays can increase where treatment for other pests like aphids have disrupted the natural enemies of helicoverpa in the crop.

**Laying foundations for effective natural enemy use**

Apart from understanding the key pests and natural enemies in sweet corn and the way they interact with each other and the crop, other non-chemical control methods that seek to suppress pest populations can play an important role in successful biological control. This is partly because many natural enemies are more likely to have an impact when initial pest populations are low.

Cultural controls such as weed management to limit the availability of host plants for pest build-up can therefore be a key prerequisite to limiting insecticide usage. Cultivation and land preparation strategies can also be important for reducing soil pest numbers.

It is a reminder that prevention of pest build-up is better than cure and, where it can be achieved, lays the best possible foundation for biological control in any crop.

# Further reading

## DPI&F information:

*Growing Guide: Sweet corn grower's guide.* Deuter, P., Wright, R., Duff, J., Walsh, B., Napier, T., Hill, L., Dimsey, R., and Learmonth, S. (2005). (Department of Primary Industries and Fisheries, Brisbane) - http://www2.dpi.qld.gov.au/agrilink/17697.html (accessed 18th Feb 2009).

*Understanding helicoverpa ecology and biology in southern Queensland: Know the enemy to manage it better.* DPI&F Brochure. 2005. QI07078.

*Microplitis demolitor and ascovirus: Important natural enemies of helicoverpa.* DPI&F Brochure. 2005. QI04079.

*Parasitoids: Natural enemies of helicoverpa.* DPI&F Brochure. 2005. QI04081.
Using NPV to manage helicoverpa in field crops. DPI&F Brochure. 2005. QI04080.

*Insect Pest Guide: a guide to identifying vegetable insect pests and their natural enemies in the dry tropics.* 2004. ISSN: 0727-6273. QI04056.

## Other publications:

*Sweet Corn Insect Pests and their Natural Enemies, an IPM Field Guide*. by Richard Llewellyn, 2000. ISBN 1 86423 972 7

## Disclaimer:

***A range of insecticides are referred to in this report. Where an insecticide is named together with ™ as a superscript, this refers to the insecticides' Registered Trade Name. This DOES NOT imply that this insecticide is registered for use on sweet corn in Australia. It is important that the registration status of all insecticides are verified prior to their application to sweet corn in Australia.***

# Appendix 3. - Milestone #5 Report – "Narrow Spectrum Pesticides with potential to contribute towards improved IPM systems in Sweet Corn"

Contributors:
John Duff[1], Austin McLennan[1], Tony Napier[2], Sonya Broughton[3], Siva Subramanian[4] and Peter Deuter[1],
[1]QLD DPI&F Gatton Research Station,
[2]NSW DPI, Yanco Agricultural Institute, Yanco NSW 2703
[3]Western Australia Department of Agriculture
[4]QLD DPI&F Bowen Research Station

**Background**

The Australian sweet corn industry has widely adopted the outcomes of VG97036, which concentrated on managing the main pest, helicoverpa.
A range of secondary pests (aphids, mites and thrips) have become major pests, as the sweet corn industry, especially in Queensland, is largely using narrow spectrum insecticides for the management of helicoverpa. A similar situation to this has occurred in other cropping systems (cotton, Brassica vegetables and tomatoes), whereby secondary pests, which were once easily controlled by broad spectrum insecticides, have become more important to these industries as more biologically based IPM systems have been widely adopted.
Some of these secondary pests of sweet corn have yield reducing effects, and others are contaminants in product destined for both domestic and export markets. The effects are product rejection (an export and domestic market access issue), downgrading and/or reduced $ returns, and reduced marketable yields.

The need to manage 'secondary' pests and diseases, whilst maintaining and/or improving the management of helicoverpa, was identified by the sweet corn industry in May 2001 (at the completion of VG97036) - "While integrated pest management (IPM) of the caterpillar pest, helicoverpa is a reality in sweet corn crops, a reduction in the use of broad spectrum pesticides for helicoverpa management has lead to this increase in the number of other pests which are now damaging sweet corn crops. Pests such as thrips, aphids and dried fruit beetles are contaminants in produce bound for export markets. Other caterpillar species, plant hoppers, mites and green vegetable bug are causing physical damage to the crop." - extract from the Final Report of Project - VG97036.

**Soft Options Assessment**

Soft Options (or Narrow Spectrum Pesticides) are an important element of IPM systems. A number of narrow spectrum pesticides have been made available to the project team through three chemical companies [Bayer/Dupont/Sumitomo]. This activity has assessed their IPM fit, and provided some efficacy data to enable these companies to proceed where appropriate with registration in sweet corn in Australia.

## Assessment of their IPM fit

- **Effectiveness of soft options against non-lepidopteran pests.**

During 2006 and 2007 seasons, four field trials were conducted in North Queensland to evaluate the efficacy of soft options against the major pest helicoverpa, and the secondary pests (aphids and mites) in sweet corn.

SCSI-01 gave very good control for corn aphids, with less than 5% infested cobs, while the untreated plots had over 60% infestation. High aphid parasitism (up to 72%) were recorded in SCSI-01 plots indicating that the product had minimal impact on the parasitoid species (Note – Taxonomic identification of the parasitoid species to be confirmed).
Both SCLI-01 and SCLI-02, applied at the early silking stage, protected the cobs from helicoverpa damage.

Avatar™ gave only a moderate level of helicoverpa control, while Symphony did not provide significant level of control compared to untreated plots.

Mite-01 suppressed the 2-spotted and red spider mite populations within 3 weeks of application, and showed minimal impact on ladybird beetle, Stethorus sp.

Trials have been conducted to assess the effectiveness of a number of soft options for the control of helicoverpa and other secondary insect pests in sweet corn in southeast Queensland. SCSI-03 has provided very good control of thrips in the early crop stages, and has extended residual effects to be able to manage aphids up to harvest, but its effect on thrips, leafhoppers and jassids still needs to be investigated, because of the low numbers of these pests in these trials. SCSI-01 also gave good control of aphids up to harvest.

SCLI-01 and SCLI-02 were very good at managing helicoverpa and sorghum head caterpillars by providing clean undamaged cobs free from caterpillars. Avatar and SCLI-03 gave variable results but were still significantly better than the control at managing helicoverpa numbers.

The residual effects of SCSI-03 appears to be good, particularly against aphids at harvest with very few aphids found on the plants within this treatment compared to large numbers on untreated plants. SCSI-01 also demonstrated effectiveness against aphids in particular, with very few aphids found on treated plants at harvest.

SCSI-01 has some effectiveness against the lepidopteran pests, even though it has been designed for use against sap sucking insects. More work will be required to determine its full potential in this area.

The WA trial compared two rates of SCLI-02, with Success™ and an untreated control.  However, due to low helicoverpa numbers (less than 0.2 larvae/plant) efficacy between treatments could not be compared.

- **Effects on beneficials.**

Trials have been conducted to assess the effectiveness of a number of soft options (SCLI-01, SCLI-02 and SCLI-03; SCSI-01and SCSI-03) for the control of helicoverpa and other secondary insect pests in sweet corn in southeast Queensland.

All the insecticidal treatments showed minimal detrimental affects on the beneficial insect populations with similar numbers of the more commonly found beneficial insects, especially the egg parasitoid trichogramma, being present in all treatments during the silking period.

Although direct field monitoring results show that the soft options are relatively safe to beneficial insects, care needs to be taken in interpreting the results. The numbers observed on the yellow sticky traps did show a slightly different story, especially with regards the trichogramma wasp.  Additional work needs to be undertaken, specifically with respect to the effects on this beneficial insect to see the true effect of these newer insecticides on the wasp population.  – see Table 1.

Laboratory trials are planned in early 2008 in WA to assess the direct effects of insecticides against beneficials including *Hippodamia* (ladybird) and trichogramma.

- **Effectiveness against helicoverpa.**

*Helicoverpa armigera* (helicoverpa) remains a major insect pest of sweet corn, especially in southern production regions.  Two trials were conducted in NSW during the 2006/07 season to assess the efficacy of a range of ‘soft option’ insecticides in controlling helicoverpa in sweet corn.  Success™ (spinosad) was included in the study as the industry standard.  The first trial was conducted at the Yanco Agricultural Institute, NSW, and the second trial was conducted on a large commercial property near Whitton, NSW.

The trials investigated the use of a number of insecticides to determine which gave adequate control of *Helicoverpa armigera* when applied to sweet corn during the silking stage.  Results showed that SCLI-01 and SCLI-02 gave statistically similar control to the industry standard of Success™ and statistically better results than the untreated plots.  The treatment of Avatar™ also gave statistically similar results to Success™ but gave no statistical improvement in helicoverpa control compared to the untreated plots.

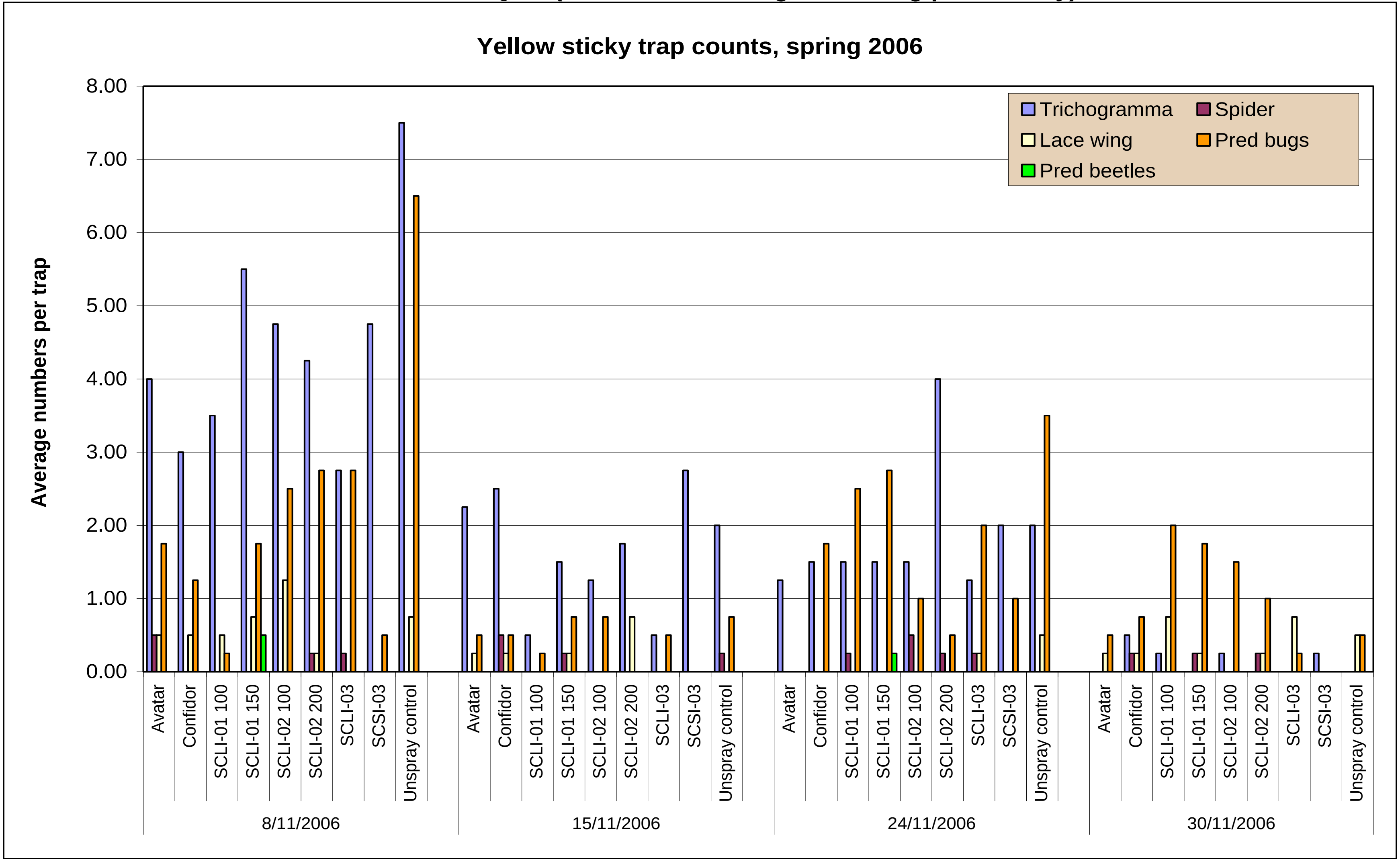
- **Efficacy data to enable these companies to proceed where appropriate with registration in sweet corn in Australia.**

A number of narrow spectrum pesticides have been made available to the project team through three chemical companies [Bayer/Dupont/Sumitomo] – Appendix II.

**Confidentiality Note -** Although this Milestone Report is not a confidential report, the information should remain confidential, until such time as the trial program has been completed (May 2008).

By May 2008, each of these companies will have made a decision on which products will be progressed through to registration. It is expected that all the information will be in the public domain by the time the Final Report has been completed in late 2008.

**Table 1.** **Numbers of beneficial insects found on yellow sticky traps placed in the crop at cob height and left there for 24 hours November 2006 – SE Qld. (Cards used during the silking period only)**

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Soft Options- available to the project team.

| Chemical Company | Company Code | Active Ingredient | Trade Name | Project Code |
|---|---|---|---|---|
| **Bayer** | NNI0001 | flubendiamide | Belt 480 SC | SCLI-01 |
| | BYI8330 | spirotetramat | Movento 240SC | SCSI-01 |
| **DuPont** | DPX-E2Y45 SC | chlorantraniliprole | Coragen | SCLI-02 |
| | DPX-HGW86 | | Soyate SC | SCSI-02 |
| **Sumitomo** | S-1812 | pyridalyl | Symphony | SCLI-03 |
| | TI-435 | clothianidin 200SC | | SCSI-03 |
| | TI-435 | clothianidin 500WG | | |
| | | etoxazole | Paramite Selective Miticide | Mite-01 |

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# Appendix 4. - Soft Options- available to the project team.

| Chemical Company | Company Code | Active Ingredient | Trade Name | Project Code |
|---|---|---|---|---|
| Bayer | NNI0001 | flubendiamide | Belt 480 SC | SCLI-01 |
| | BYI8330 | spirotetramat | Movento 240SC | SCSI-01 |
| DuPont | DPX-E2Y45 SC | chlorantraniliprole | Coragen | SCLI-02 |
| | DPX-HGW86 | | Soyate SC | SCSI-02 |
| Sumitomo | S-1812 | pyridalyl | Symphony | SCLI-03 |
| | TI-435 | clothianidin 200SC | | SCSI-03 |
| | TI-435 | clothianidin 500WG | | |
| | | etoxazole | Paramite | Mite-01 |

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