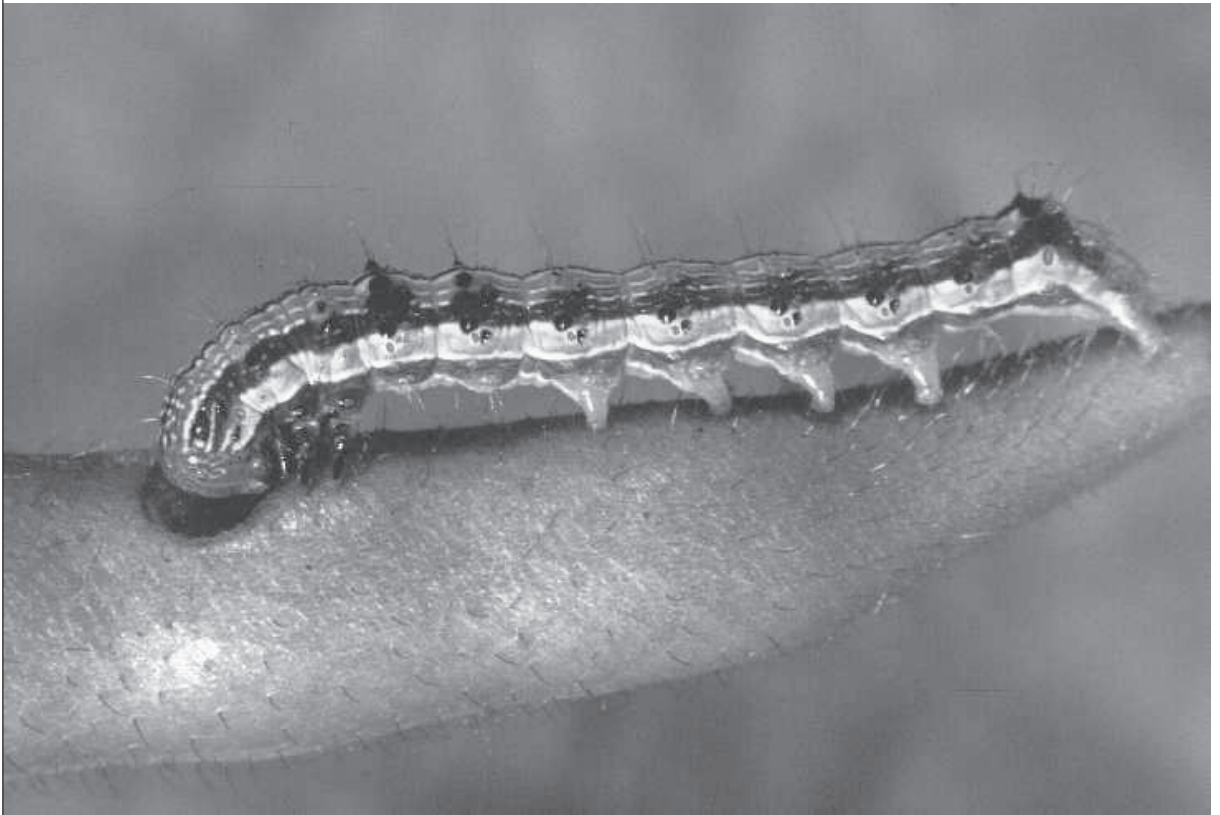


National helicoverpa workshop report



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21 & 22 June 2004

Department of Primary Industries and Fisheries, Toowoomba

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DPI&F delivers outcomes that maximise the economic potential of primary industries along the value chain with a focus on improving competitiveness, productivity, innovation and export earnings. This is achieved through the sustainable use of resources to ensure the long-term future of primary industries.

This publication provides the outcomes of a national workshop on helioverpa that reviewed the developments in research, development and extension (R,D&E) related to helioverpa management in Australia, reviewed the role of extension in the development and implementation of Area-Wide Management (AWM) programs by growers in north-east Australia, examined the prospects for successful AWM, and provided direction for future R,D&E requirements for these pests.

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Executive Summary

Helicoverpa spp. are arguably Australia's most important insect pests, costing the economy \$200-300M annually. Significant advances in the management of *helicoverpa* have been made since the last workshop in 1995.

A two day workshop at Toowoomba on 21-22 June 2004 provided an opportunity for around 50 participants with interest in *helicoverpa* R,D&E from State Agriculture Departments, CSIRO, Universities, R&D Corporations, consultants and industry to discuss issues related to the management of these pests in grains, cotton and horticulture. The first day involved a series of short review presentations to set the scene, followed by questions and discussion from the floor. The second day involved workshopping sessions to tease out priority issues, identify gaps and provide direction for future research.

The objectives of the workshop were to:

- (a) review the developments in R,D&E related to *helicoverpa* management in Australia since the last workshop;
- (b) review the role of extension in the development and implementation of Area-Wide Management (AWM) programs by growers in north-east Australia;
- (c) examine the prospects for successful AWM, and
- (d) provide direction for future R,D&E requirements for these pests.

Whilst the focus of the workshop R,D&E concerned with advancing knowledge and management capacity of *Helicoverpa* spp., there was some discussion about the benefits that could accrue to industries or regions, or in managing other pest species, from extending techniques used successfully with *helicoverpa*.

DEVELOPMENTS IN R,D&E RELATED TO HELICOVERPA SINCE 1995

Area wide management

In 1995, AWM was discussed as a desirable goal, but was considered to be unlikely to succeed because of the gaps in knowledge of regional ecology of *helicoverpa*, and the practical difficulties associated with getting AWM-related management tactics adopted voluntarily by growers across a large enough geographic area to have an effect on the *helicoverpa* population. In 2004, there are groups of growers from Emerald to Warren identifying themselves as AWM practitioners and participating in AWM groups. R,D&E has been supported in the northern region (particularly central Queensland, and the Darling Downs) jointly by GRDC and CRDC, focussing on broadacre cropping systems (grain and cotton). AWM is seen to have contributed significantly to the increased interest in IPM, and to some extent the decrease in the *helicoverpa* pressure in the past 3 seasons in the northern region.

Transgenics insecticides, and resistance

The introduction of Bt cotton, and the imminent deployment of the two-gene cultivars, have and will continue to have a major impact on insecticide use in the cotton industry. The introduction of a number of target-specific insecticides in recent years has contributed to the 'soft' options available in cotton and horticulture, and

facilitated the implementation of IPM. The availability of these products for grain crops continues to lag behind these other industries. The rapid development of insecticide resistance is still challenging the longevity of new products.

Natural enemies

There has been a major effort in many industries to raise the awareness of natural enemies, and promote their role in IPM. Success with individual species, for example *Trichogramma* in cotton, sweet corn and tomatoes, has raised the profile of natural enemies amongst growers and consultants. Ongoing R&D to produce identification and monitoring tools, in conjunction with hands-on learning, means that growers are increasingly aware of the benefits natural enemies offer. Many are increasingly able to incorporate natural enemies into their pest management decision-making. There are, however, still considerable gaps in knowledge of the basic biology and ecology of most predators and parasitoids, and in how to maximise and quantify their impact in pest management.

Biopesticides

NPVs have been widely adopted for the control of helioverpa in the grains, cotton and horticulture industry, particularly for sorghum and sweet corn. Ongoing research on application and additives is finding ways to improve the efficacy of NPVs. Extension activities have been key to the uptake of NPV, particularly in the grains industry.

Semiochemicals

Advances in analytical chemistry and insect physiology have resulted in the development of plant-based volatiles (kairomones) that can be deployed in an attract-and-kill product. A commercial formulation of a helioverpa attractant (Magnet®) was trialed in 2003-4, with a view to being registered for use by 2005.

Forecasting movement and abundance

There is little ongoing work in the area of forecasting. However, with the growing interest in AWM of helioverpa in recent years, there has been renewed interest in the potential to forecast regional abundance and immigration events, and to evaluate the role of climate and/or management activities on pest abundance.

Application of DNA techniques

DNA technology has been applied to the study of migration (microsatellites) and diagnostics in recent years. The work on migration has evaluated the quantity and direction of helioverpa movement in eastern Australia, and some sites in western and northern regions. More recently, this technique has been applied to monitoring the development of insecticide resistance. DNA techniques for determining the identity of helioverpa (*H. armigera* or *H. punctigera*) are well established. The application of techniques for detecting parasitism and infection with NPV and ascovirus are being developed for use in monitoring field populations.

THE ROLE OF EXTENSION IN THE DEVELOPMENT & IMPLEMENTATION OF AREA-WIDE MANAGEMENT

A focussed extension effort has been credited with much of the success associated with the high level of awareness of AWM and the participation of growers in groups that meet under an AWM banner.

Area-wide management has been extended in Central Queensland, on the Darling Downs, and in cotton-growing districts throughout Queensland and New South Wales. In CQ and the Darling Downs, the extension has been undertaken in conjunction with R&D as part of projects specifically designed to promote and implement AWM. In other regions, the industry development officers of the National Cotton Extension Team have played a role in local groups identifying themselves as AWM groups.

The formation of local groups with a common goal has contributed significantly to breaking down barriers between grain and cotton growers, and building social capital on a local level.

In discussion throughout the workshop, extension was identified as a major priority in succeeding with the education of growers, and the adoption of new technology and techniques. Repeatedly the AWM group network was identified as a vehicle for extending information and monitoring the impact of research (level of adoption and practice change).

Whilst it is perceived that the absence of a crisis in helioverpa management in recent seasons has reduced the enthusiasm of growers for AWM, the rise of IPM as a focus for groups is a natural progression from the AWM focus. It is anticipated that many of the groups will continue to function under an IPM banner, or broaden their focus to provide general agronomy and pest management support to members. Members of current groups may reform in new groups based on IPM-related issues rather than geographic location. This changing focus will also open the way for new participants who may have felt unable to participate in existing AWM groups.

PROSPECTS FOR SUCCESSFUL AREA-WIDE MANAGEMENT

It has been difficult to evaluate the impact of the Helioverpa Regional Management Strategy on the size of the local helioverpa population, with the impact of the dry winter/spring over the past four seasons conflating the potential impact of trap cropping, pupae busting, sub-threshold use of NPV and increased awareness of management in grain crops.

However, there was general enthusiasm amongst the workshop participants for what AWM could offer, in terms of population management of helioverpa on a regional basis, and beyond. The concept of working across commodities and farms was seen as having wider application than to the grains and cotton system in the northern region.

The deployment of semiochemicals for area-wide population management is one area that is already being tested. The prospect for the management (cultivation,

preservation) of natural enemies on an area-wide basis was mooted. Silverleaf whitefly is another species identified as requiring an area-wide approach to be successfully managed, particularly in regions where there are both broadacre and horticultural crops in close proximity.

PRIORITISED R,D&E NEEDS FOR HELICOVERPA

At the end of the workshop, participants had analysed the current situation, defined what needed to be done to improve helioverpa management in general, and specifically in relation to AWM. Participants developed a list of R,D&E priorities to guide future industry investment.

The issues identified as high priority in each activity area were as follows.

Area Wide Management

Building on existing knowledge and successes

Opportunities exist to create linkages across industries, particularly where the same pest is being managed e.g. helioverpa, SLWF. There is potential to extend AWM to pests other than helioverpa. Constraining this may be differences in the attitudes and culture of the different industries, conflicting priorities, and a history of individualism amongst growers (e.g. vegetable growers).

The benefits of progressing AWM beyond its current application in the northern region, grains-cotton context were seen as significant. For example, benefits would accrue in relation to IPM, insecticide resistance management, networking by growers and grower education.

There are challenges to both the existing, and any new, AWM programs. Principally these are associated with gaining and maintaining interest amongst growers to manage pests when not in crisis (severe pest pressure and loss). Addressing these challenges requires the input of government extension staff, the enthusiasm of growers and an ongoing extension effort. There is a significant risk of complacency amongst growers when pest issues are not at a crisis level, and other issues are pressing e.g. drought, water.

Natural Enemies

Basic knowledge of natural enemies in IPM

Current knowledge about all aspects of natural enemy biology and ecology is limited. Most significantly there is little knowledge of which species are, or are capable of, making a significant contribution to pest control. Other knowledge gaps identified were

- Appropriate sampling and monitoring techniques for research, and for growers/consultants
- The impact of new insecticides and additives (e.g. salt) on natural enemies
- The potential to manipulate the farming system to create nurseries and/or refuges for natural enemies (e.g. through the application of moth/host attractants)
- The impact of transgenic crops on natural enemies

Using naturally occurring populations of natural enemies

The conservation and enhancement of naturally occurring populations of natural enemies is desirable (as opposed to rear and release). This approach would be viewed favourably by the community as 'green' and sustainable.

Economic analysis of natural enemy impact

Economic analyses of the cost:benefit of using natural enemies in pest management would be of benefit in promoting IPM, and particularly the value of natural enemies. The analyses would enable a dollar value to be put on natural enemies, for consideration by growers/adopters. The skills to do these analyses need to be sought.

Funding and employment in the field of natural enemy research

There is a benefit in forming a natural enemy working group to build collaboration amongst participants, and raise the general awareness of ongoing research in this field. Participants felt that because natural enemy research is not recognised as an established field of research in Australia, there are major challenges in maintaining research programs in this area.

Extension

Coordinating/integrating service delivery – linking across industries

There was benefit seen in looking for opportunities to integrate/coordinate the extension effort across:

- Industries
- Organisations
- Sectors (public – private)
- Extension providers

Resourcing to maintain the extension services would be facilitated by this coordination, and by formal linkages across industries. The use of larger networks and user-pays services would maintain and protect the quality of the extension provided.

Packaging, re-packaging and new extension approaches

There is a need for user-friendly information to be available to would-be adopters. The packaging of information needs to be responsive to the situation, and current for the industry. It may require re-packaging to stay relevant and connect with clients. It is important to take a proactive approach to developing and using new models of extension and knowledge management. There is a risk of being constrained by the extension status quo that exists currently within industries.

Evaluation

Valuing evaluation

Evaluation, in all its forms, was seen as extremely important. Of highest priority was developing an across-the-board (from stakeholder to client/end user) understanding of the use of evaluation at each level. This understanding would then guide the evaluation approach for R,D&E, be it formative, summative or iterative.

Skills and processes for evaluation

Within the existing networks of helicopterpa R,D&E, there is limited expertise in evaluation. Building, or accessing, these skills is imperative to ensure that evaluation

is within the scope of all projects. The involvement of social scientists in evaluating and understanding the drivers for change was seen as being as important as economic evaluation. Improved evaluation will enable achievements to be reported in the context of farm, region, industry etc – of benefit to researchers, extensionists and stakeholders.

Identify key areas for evaluation

Benchmarking is an accepted form of evaluation, but is dependant on the ongoing collection of data to enable comparisons. The maintenance of key data sets needs to be supported, as do the skills to use the large data sets – modelling, database management.

Climate, Movement and Forecasting

Collection and accessibility of data

An ability to forecast is dependant on the availability of long-term data sets. Whilst there are a number of data sets held by different organisations, many have not been long-term, nor have they been linked in a way that would allow analysis. Funding is needed to ensure the collection of appropriate data (meteorological, farm) and the infrastructure to maintain the data sets (e.g. web-based).

Forecasting and prediction

The potential for forecasting and prediction on a local, regional and national level is large –for research and for field applications. New technologies, advances in climate modelling and DNA technology offer opportunities.

Pest movement/population dynamics and DNA

Studying pest movement and population dynamics, particularly using DNA tools (e.g. microsatellites), has the potential to allow pest managers to be more prepared and less reactive. Information on a more local level would allow insect models to be linked to farming system models, and to examine refuge options/effectiveness in relation to gene flow.

Insecticides and Transgenics

Balanced approach

There is a perceived complacency in the industry (cotton) in relation to what transgenic crops will mean in terms of pest management. The group identified a need for an integrated approach to the deployment of transgenic crops which ensures the maintenance of knowledge and skills in managing pests in non-transgenic crops.

Resistance management

Ongoing monitoring of resistance trends is important, including the development and deployment of rapid monitoring techniques. There are opportunities to integrate a wider range of options, as they become available e.g. new genes, insecticides (particularly those with new modes of action), within crop management. There was concern about the implications that the widespread introduction of transgenic cotton will have for the progressing of new insecticides, Uncertainty about the practicalities of managing resistance if it is detected.

Biopesticides

Addressing grower perception of performance

Grower confidence in NPV is influenced by the perception they have of the performance of the product. The perceptions growers hold of NPV is highly variable based on experience in different crops, at different pest pressure and speed of kill. In some instances, grower enthusiasm for NPV exceeds the real potential of the product. Grower education is essential to ensure confidence in NPV is maintained and built on.

Make them work!

To ensure that biopesticides are used as effectively as possible, R&D needs to continue to develop and refine techniques for maximising their efficacy in the field. Investigation in the areas of additives, the dose and frequency of application, and timing of application are warranted. Genetic manipulation of biopesticides may improve performance.

Semiochemicals

Evaluating a new tool – potential applications Semiochemicals represent a new option in pest management that is not a pesticide. Potentially, semiochemicals offer an option that will reduce the need for insecticide, or replace some insecticide applications. The cost:benefit analysis of semiochemicals needs to be done in this context, because the products themselves are potentially costly in comparison with conventional insecticide options. There may be some off-target impacts of the semiochemicals in an 'attract and kill' mode; these impacts need to be evaluated.

The application of semiochemicals to current and evolving IPM programs needs to be investigated. They are potentially tools for the area-wide management of *Helicoverpa* and resistance management in conjunction with transgenic crops. In these contexts, information on the movement of moths and the forecasting of local emergence will be essential.

Regulation

Regulatory authorities are unfamiliar with the use of semiochemicals, and currently the registration of such products face the same process that is applied to insecticides, which may not be appropriate.

DNA Applications

Understanding what DNA-based tools can deliver

Scientists and growers are largely unaware of the potential application of DNA techniques to their work. There is a need to increase the general level of awareness of the opportunities, and the potential benefits of using these tools.

Workshop Agenda

MONDAY 21ST JUNE

- 9.00am Chairperson Session 1: David Murray
Workshop Starts – Welcome & Introduction (10 min)
- 9.10am **National Perspectives of R,D&E**
GRDC – John Sandow (10 min)
CRDC – Greg Kauter (10 min)
HAL – Discussion (5 min)
Cotton CRC – Lewis Wilson (5 min)
Discussion (15 min)
- 9.55am **State Perspectives**
Qld & NSW – Gary Fitt (12 min)
Southern States – Dennis Hopkins (12 min)
NW States – Discussion (12 min)
- 10.30am Morning tea
- 11.00am Chairperson Session 2: Austin McLennan
Process Instruction - John Rogers (5 min)
- 11.05am **Area Wide Management**
Overview and Why we're here – David Murray (30 min)
- 11.35am **Insecticides & Resistance** – Robin Gunning (10 min)
Biopesticides & Resistance – Carrie Hauxwell (10 min)
Transgenics & Resistance – Rod Mahon (10 min)
Discussion (20 min)
- 12.30pm Lunch
- 1.30pm Chairperson Session 3: Brad Scholz
Natural Enemies – Peter Ridland (15 min)
Climate, Movement & Forecasting – Meron Zalucki (15 min)
DNA Applications – Kirsten Scott (15 min)
Semiochemicals – Peter Gregg (15 min)
Discussion (30 min)
- 3.00pm Afternoon tea
- 3.30pm Chairperson Session 4: Paul Grundy
Novel Options – Expressions of Interest (OHP Presentations ONLY)
Petroleum spray oils – Robert Mensah (5 min)
Helicoverpa genomics – Karl Gordon (5 min)
Thresholds – Hugh Brier (5 min)
Extension & Area Wide Management – Austin McLennan (15 min)
Evaluation – Martin Dillon (15 min)
Discussion (30 min)
Voting (5 min)
- 5.00pm Close
- 7.00pm Dinner at Crazy Gallaghers, Wilsonton Hotel/Motel, Richmond Drive

TUESDAY 22TH JUNE

- 8.30am Recap & Rev-up (10 min)
Day 1 Highlights
Session 2 – Rob Annetts (5 min)
Session 3 – Matthew Holding (5 min)
Session 4 – John Slatter (5 min)
Voting Results & Discussion (30 min)
- 9.30am **Group Session Topics 1**
Insecticides & Transgenics
Natural Enemies
DNA Applications
Semiochemicals
Evaluation
Split into 5 groups for Topic Discussions (60 min)
- 10.30am Morning tea
- 11.00am **Reporting Back on Group Session 1 (50 min)**
5 Groups (10 min for each group)
- 11.50am **Group Session Topics 2**
Biopesticides
Climate, Movement & Forecasting
Novel Options
Extension
Area Wide Management
Split into 5 groups for Topic Discussions (40 min)
- 12.30pm **Address by Peter Reading, Managing Director, GRDC (15 min)**
- 12.45pm Lunch (including GRDC Northern Regional Panel)
- 1.30pm Resume **into 5 groups to complete Topic Discussions (20 min)**
- 1.50pm **Reporting Back on Group Session 2 (50 min)**
5 Groups (10 min for each group)
- 2.40pm Contents of Workshop Report – David Murray
Invertebrate Pest Initiative – Gary Fitt
Evaluation of Workshop
Wrap-up
- 3.00pm **Close**

Background to the Workshop

Much has happened since the last National Helicoverpa Workshop in 1995, so this workshop was well overdue. The two day workshop provided an opportunity for around 50 participants with interest in helicoverpa R,D&E from State Agriculture Departments, CSIRO, Universities, R&D Corporations, consultants and industry to discuss issues related to the management of these pests in grains, cotton and horticulture. The first day involved a series of short review presentations to set the scene, followed by questions and discussion from the floor. The second day involved workshoping sessions to tease out priority issues, identify gaps and provide direction for future research.

Workshop Objectives

The objectives of the workshop were to:

- (a) review the developments in R,D&E related to helicoverpa management in Australia since the last workshop;
- (b) review the role of extension in the development and implementation of Area-Wide Management (AWM) programs by growers in north-east Australia;
- (c) examine the prospects for successful AWM, and
- (d) provide direction for future R,D&E requirements for these pests.

Who was involved?

A wide range of stakeholders involved in the cotton, grains and horticultural industries who have relevant experience and information about current practices, research and potential options for the future. This richness of experience was one of the most important aspects of this workshop because participants all brought knowledge and experience to the workshop that, when shared with others, helped us to develop projects even better than each of us could find alone. Everyone had a very important part to play, whether their background was in research, farming, consulting, extension or agribusiness.

People were invited to represent the following topic groups:

- Area Wide Management
- Insecticides and Resistance
- Biopesticides and Resistance
- Transgenics and Resistance
- Natural Enemies
- Climate, Movement and Forecasting
- DNA Applications
- Semiochemicals
- Novel Options
- Extension and Area Wide Management
- Evaluation

Workshop Outcomes

At the end of workshop, participants had analysed the current situation, defined what needs to be done to improve helioverpa management in general and specifically area-wide management. Participants also developed a list of R,D&E priorities to guide future industry expenditure.

Topics for Group Session 1

- Insecticides and transgenics
- Natural enemies
- DNA applications
- Semiochemicals
- Evaluation

Topics for Group Session 2

- Biopesticides
- Climate, movement and forecasting
- Novel options
- Extension
- Area Wide Management

Session 1: National Perspectives of R,D&E

A grains perspective on helioverpa research

by John Sandow GRDC Canberra

Through the 1980s and 90s helioverpa management was mostly about chemistry, but it is now a much more diverse topic. The 2000s have seen a hush of expectation with a felicitous combination of events. A positive feedback loop has encouraged better IPM; the better IPM works, the better IPM works. The extension effort has engaged growers and led to better adoption.

Future

- Understand where we are now and how to go forward. The landscape has changed, but current thought processes have evolved in the chemical landscape. We need to consider whether the approach needs to change fundamentally to reflect the changed landscape.
- Maintain momentum to broaden success across all systems to lessen helioverpa activity
- Take the lessons of success with helioverpa and deliver them to other pests and/or systems. IPM must be broadened across industries, but currently the R&D corporations are not organising themselves to facilitate this happening.

Helioverpa – cotton perspective

by Greg Kauter CRDC Narrabri, Australian Cotton CRC

What is the history of helioverpa R,D&E funded by your organisation?

Helioverpa are the key pests of cotton and have been a major focus of CRDC's funding since the Corporation was established in 1990. Areas of study have been very broad and have included: Ecology, ecological and population genetics, population dynamics (including in inland Aust) and modelling (HEAPS and predictive), adult and reproductive behaviour, migration, egg and larval survival, feeding behaviour, resistance monitoring, insecticide efficacy, IPM systems (development, testing, extension, training, inclusion in BMP program), impact and efficacy of beneficials (predators, including use of foodsprays and parasitoids including mass release and conservation), biological insecticides (NPV and others), use of pheromones for monitoring and control, potential for new and novel transgenes (other than Bt), introduction and management of Bt cotton (including refuge crop management, sampling, seasonal efficacy, economic performance), genetic differentiation, ID & predictive classification of Australian Heliiothines, genetic mapping of H.a., cultural control (pupae busting, trap cropping), behavioural control (semio chemicals, prior learning, petroleum spray oils), host plant resistance (eg. okra leaf), plant compensation, area wide management, decision support systems (entomoLOGIC, cottonLOGIC, IPM Guidelines, Beneficial Disruption Index).

The additional research capacity provided through the two cotton CRCs since 1994 has added to many of the areas above as well as developing other novel technology such as the helioverpa attractant Magnet and the coordination of a highly effective extension network.

Extension has involved all members of the Cotton Extension Network, Insect Focus team, development of IPM Guidelines, development of an IPM Training Course for growers, impact of insecticides on beneficials, facilitation of AWM groups, benchmarking, evaluation of extension, pest and beneficial identification, implementation of BMP.

What were the main issues behind this R,D&E activity?

Recognition that helioverpa are the key cotton pests and have the potential to threaten the sustainability of the industry has driven the need for understanding the basic ecology and movement of both helioverpa, monitoring and managing insecticide and Bt resistance in *H. armigera*, development of IPM systems that reduced reliance on broad spectrum chemistry, conserved and used of beneficial species and introduced a range of non-chemical control methods (biopesticides, cultural controls etc.) and incorporation of Bt cotton.

What have been the bigger picture outcomes from helioverpa R,D&E?

Successful deployment and management of Bt cotton, continuously improving IPM systems, successful and pro-active resistance management for both insecticides and Bt, rapid reduction in quantities of insecticides used, establishment of area wide management concept, use of a range of non-chemical control methods. Joint and collaborative R&D with grains at the farming systems level.

What do you think are the major challenges facing helioverpa R,D&E?

Successful deployment and management of Bollgard®II cotton in the cotton/grains farming system including management of Bt resistance and IPM of sucking pests. Continuing to improve the IPM system for conventional cotton. Insecticide resistance management across the whole farming system. Developing an understanding of the impact of new technologies and management on the ecology of the pest (esp. *H. armigera*).

Where do you see funding for helioverpa R,D&E going in the future?

Bt resistance mechanisms, monitoring and management, joint cotton/grains monitoring and management of insecticide resistance, development and deployment of novel control technology and use in IPM systems, further development and support for AWM groups and regional pest management.

Cooperative Research Centres

Discussion

Lewis Wilson outlined the new submission for the Cotton Catchment Communities CRC. The proposal has a much broader content than the current Australian Cotton CRC. Areas identified for potential funding in the new CRC included area wide management, IPM, new regions, novel tools and decision support tools. It was envisaged there would be a modelling component and further research into movement.

National funding perspectives

Discussion

- On ground resources dwindling
- QDPI&F (Horticulture) funds 3 plant protection teams
- IPM important part of environmental protection – opportunity for funding access?
- Collaboration between industries
 - Physical proximity of crops helps
 - Relationships between staff important
 - Should lead farming systems changes, not only be reactive, e.g. Burdekin
 - Different cultures exist
- Secondary pests will be a significant issue in changing farming systems
- More scope exists for other collaboration e.g. Decision support tools could be marketed to horticulture
- CRCs present big opportunity for cross industries collaboration

State Perspectives

Helioverpa: a Qld and NSW perspective

by Gary Fitt CSIRO Entomology, Australian Cotton CRC

Helioverpa – pest status...

- *H. armigera* abundant in north, declining to south
- *H. punctigera* can be locally abundant anywhere
- Well adapted to multi-cropping systems

- Significant control costs and damage (\$200-\$300 million per annum)
- Diapause, migration
- Resistance in *H. armigera* – pesticides
- GM cotton?

Helicoverpa R,D&E... key drivers

- Changing, diversifying, intensifying cropping systems (with irrigation) - impacts on helicoverpa abundance and damage
- Extensive reliance on pesticides
 - Pesticide resistance
 - Rising costs of new pesticides and hence economics of pest control
- Environmental impacts of agricultural production
 - Specific concerns about pesticide contamination and residues in livestock
 - Impetus for IPM and development of accredited BMP or EMS approaches
- Southern NSW cropping systems – growing presence of cotton and changing suite of grain crops.
- Need for research and management of helicoverpa on a regional or area wide basis
- Introduction of Bt cotton technology in 1996 – key issue in the cotton industry and perhaps regionally.

Helicoverpa R,D&E... major outcomes

- Significant gains in IPM adoption where adequate extension support available – pest management better integrated to farming system
- Few gains in some industries
- Transgenic Bt cotton
- Other IPM compatible tools (beneficials, biopesticides, semiochemicals, non-disruptive synthetics, information support tools)
- Significant pesticide savings in some industries
- AWM supported by enhanced understanding of pest movement and population structure (genetic markers, pollen, GIS)
- Resistance management strategies (pesticides and GM) in place, but patchy
- Extension support has been critical

Explicit use of beneficials

- Soft chemistry
- Bt cotton – non-disruptive
- Habitat manipulation
- Other resource needs

Helicoverpa R,D&E... challenges

- Resilience of resistance management strategies
- Coordinated deployment of GM crops
- Critical need for enhanced education and training of growers/ advisors in IPM and new technologies
- Better coordination of R,D&E
- Compatibility of production and environment
- Lack of access to new technologies in small markets
- Changing pest spectrum – complicates IPM
- Reduced R,D&E funding – helicoverpa issues solved!
- Impact of climate change on pest and crops

Helicoverpa R,D&E...the future

- Widespread acceptance of cross-industry interactions – facilitates AWM and joint funding
 - Clarification of adult movement using markers
 - Operational forecasting at local and regional scale
- New transgenics (beyond Bt genes) with well supported management systems
- Increase in biological/ genetic options
- ...in particular role of beneficials and importance of non-crop vegetation (remnants, on-farm habitats)

- Cost-effective IPM for a wider range of crops
- Integration of pest management into BMP/EMS

Pest status in southern States - SA, Vic and Tas

by Dennis Hopkins SARDI Adelaide

What is the brief history of pest status of helioverpa in your region?

SA - H.punctigera major pest of pulse (field peas, faba beans, lupins, lentils & vetch) and oilseed (canola) crops throughout the state. Flights in spring lead to problem generation in September/October period. Monitoring of crops widely practiced. Treatment thresholds available for most crops. A single pyrethroid application usually gives effective control. H.punctigera also a major pest in seed lucerne crops in mid to late summer. Effectively managed with pyrethroids or endosulfan. H.punctigera considered to be relatively minor pest of a range of horticultural crops. Most tomatoes now grown under cover. H.amigera not considered a pest in SA; recorded on just a few occasions. VICTORIA (info provided by Peter Ridland) - H punctigera in pulses and oilseeds; situation same as in SA. Local populations of H amigera have caused significant problems in sweet corn (Bairnsdale area), lettuce (Werribee & Cranbourne areas) and field tomatoes (processing and fresh in the Tatura area). H punctigera also a problem in field grown tomatoes. Problems occur mainly in February/March and insecticide resistance is the main issue.

TASMANIA (info provided by Lionel Hill) - H punctigera is an important pest of green peas, beans and poppies. Damage caused by spring generation and is currently managed successfully with pyrethroids. Both H punctigera and H amigera are pests in sweet corn, usually during February. Being successfully managed with Success and pyrethroids. Both species are not known to overwinter in Tasmania and any activity is dependent on migratory flights from the mainland.

What were/are the main issues triggering R,D&E activity in your region?

SA - No major research activities at present. Last work done in 1980's; phasing out of DDT and phasing in of pyrethroids. Also, studies done on effective timing of pea weevil and H punctigera pesticide applications in field peas.

VIC - Similar to SA for pulse crops. Main issue triggering R, D & E in sweet corn, lettuce and field tomatoes has been pyrethroid resistance in H amigera.

TAS- No significant R, D & E activity for a long time. Light trap run at Devonport provides warning of major flights. This prompts closer monitoring and industry seems to manage problems in sweet corn with Success® and pyrethroids.

What have been the bigger picture outcomes from helioverpa R,D&E in your region?

SA - with monitoring techniques and threshold established for most crops, H punctigera generally managed successfully throughout the state.

VIC - H punctigera in pulses and oilseeds managed well with pyrethroids. R&D in sweet corn, lettuces and field tomatoes over recent years has led to improvements in crop scouting efforts and use of alternative products (ie Success® & Gemstar®) and this has resulted in acceptable management of H amigera in these crops.

TAS - With H amigera in sweet corn, monitoring and alternatives to pyrethroids (Success®) seem to be providing acceptable management practices.

What are the major challenges facing helioverpa R,D&E in your region?

No major challenges in managing H punctigera in the South Eastern region as existing practices with pyrethroids are considered to be sustainable for the medium to long term. With H amigera, major challenge will be to manage insecticide resistance. Over recent years, general management of H amigera in Victoria and Tasmania seems to have stabilised for reasons mentioned above but it is likely that recent population pressure (last two to three years) has been low due to the drought conditions experienced in Eastern Australia.

Where do you see helicoverpa R,D&E going in the future in your region?

No major research activity currently proposed for the South Eastern Region. Region probably dependent on information on resistance management for *H. armigera* to come from other programs around the country.

State perspectives – Northern Territory and Western Australia Discussion

The primary focus of helicoverpa research in northwest Australia relates to the development of cotton in northern Australia, and the place for transgenic Bt cotton given its ability to greatly reduce insecticide use. Research continues at Kununurra, Broome and Katherine. In the broadacre cropping areas of south-western Australia, *H. punctigera* is monitored using a network of pheromone traps. This early warning system alerts growers (particularly lupin producers) to potential pest outbreaks in the spring. Problems with *H. armigera* and *H. punctigera* were identified as being similar to those encountered in horticultural crops in other regions of Australia.

State perspectives Discussion

- Need techniques to separate impact of AWM and natural variation in pest pressure
- In horticulture crops in Victoria, supermarket QA programs have driven change in chemical choice and increased scouting

Session 2:

Area wide management overview

by David Murray QDPI&F Toowoomba, Australian Cotton CRC

What work is being conducted?

Over the past 5 years, emphasis has been on the development, implementation and evaluation of AWM strategies suitable for cotton/grains farming systems. It has largely involved working with smaller grower groups (AWM or IPM groups) of 8 to 12 growers and their agronomists.

Why is this work being conducted - issues?

The main purpose of AWM is to reduce reliance on insecticides and foster the adoption of IPM approaches. A crisis situation had developed through the 1990s where management of helicoverpa potentially threatened the viability of cotton and grain production. In cotton on the Downs, insect pest management costs had soared, in some cases exceeding \$1000/ha. This was the result of insecticide resistance and persistent, high pest pressure. AWM was in response to the economic, environmental and social issues associated with this high insecticide reliance. Central Queensland was the first region to drive AWM in their efforts to secure Ingard as an option for cotton production (Richard Sequeira). It preceded AWM efforts in southern growing districts. AWM has developed as a farming systems approach to pest management. See the attached AWM strategy for the Darling Downs. While the principles behind AWM were sound, the achievement of reduced pest populations was always going to be a challenging goal that would prove difficult to measure.

Who are the key workers in this area?

DPI&F (Southern & Central Queensland), UQ (Meron Zalucki, Glenn Graham, Leon Scott, Kirsten Scott, Wayne Rochester & others) , CSIRO (Martin Dillon) and NSW Ag (Ziaul Hoque and Bob

Farquharson). AWM activities have drawn heavily on Industry Development Officers, Extension Agronomists, Consultants and growers.

What are the key findings and their implications?

AWM is a successful and complex process and needs to be refined to suit local conditions. Ongoing R,D&E activity is needed to support improved pest management approaches and facilitate adoption of IPM.

AWM activities have aided information flow in all directions - newsletters, group meetings, farm walks and visits.

AWM activities have helped identify gaps in knowledge and determine where to next?

What are the bigger picture outcomes? How would you quantify and measure these?

Question: Has AWM reduced pest abundance in an area?

Much has happened over last 5-7 years, and more changes are taking place.

Immigration was considered a major obstacle for AWM as it was beyond the control of local activity. DNA microsatellites and spatial analysis studies have helped address the 'local' versus 'immigrant' issue.

There has been a conscious efforts to reduce insecticide use - it is a measurable benefit

Attitude change is more difficult to measure. What do you attribute it to?

There has been a growing trend towards conservation of natural enemies and their consideration in decision-making and insecticide selection.

A greater awareness of pest management issues has developed and this is not confined to helicoverpa e.g. green mirids, silverleaf whitefly, GVB. Inter-relationships are considered - different pests and their management effects.

Industries are in a more comfortable position than 5 years ago - more knowledge, more effective choices. The latter seems the most important consideration BUT therein lies a risk of falling back to 'silver bullet' mentality.

What are the major challenges in this area of work?

Evaluation.

Lack of control areas.

Needs to be grower driven - 'local' leaders tire over time; they need replacement/rotation.

We need to repackage information - deliverers tire over time; need rejuvenation.

Growers are now asking more difficult questions; ones that we don't have the answers to.

Maintaining the momentum and enthusiasm when other issues take priority e.g. water and drought, particularly when pest pressure is relatively low.

AWM versus IPM - are they really different?

Problems with fly-ins (immigrants) and local 'hot spots'.

Thresholds are not well defined in most crops. They work, but are they too conservative? Conflicting issues e.g. chickpea - low early damage versus population management.

Losing way when the going gets tough and the return of old habits.

Taking risks and stretching the comfort boundaries.

Where do you see this work going in the future?

Grains & cotton are now in a much better position than 5 years ago.

Growers and consultants are in a comfort zone - real or perceived!

Need to maintain the flow of information and reinforce messages.

Changing situation especially with the adoption of Bollgard®II - wait and see attitude!

Need to monitor changes in pest and beneficial activity.

IRMS for farming system - will it be maintained or return to a free for all?

Coordinated AWM.

Incorporate management of all pests in the farming system.

Discussion

- Water limitations, and the value of water in areas closer to urban markets, may drive an increase in horticulture in some areas that are currently predominantly broadacre
- In mixed broadacre-horticulture areas (e.g. Emerald), where the area of horticulture is expanding, will not get far with AWM unless horticulture is involved. Not just of helioverpa, but also SLWF and potentially other species.
- Is complexity of horticulture an advantage?
- Need to think about the application of AWM to horticulture – how should this be approached? Can we identify what specific activities have had an impact and generated change? These are the areas which would be profitable to duplicate in horticulture.
- Spectrum of understanding and implementation of AWM, from simple to complex
- Need a common understanding of terms (eg. IPM, AWM) for all stakeholders
- Grower awareness that IPM extends beyond farm boundary is beneficial – this is what AWM has done
- IPM is a term used loosely, IPM is not easy to do well
- Do consultants know enough about alternative tools in IPM? Beneficials, environmental factors, etc. The education of these advisers is important
- Risk aversion study underway for biopesticides, as tools in IPM (Reeson, Hauxwell, Hickman – A survey of grower attitudes to biopesticides and the risks associated with their use)
- Need a better handle on what makes growers tick in terms of decision making, information processing and how to package information in ways growers relate to
- Growers need better systems-level understanding of populations and management impacts – confidence in IPM
- Models may be useful in identifying what specific components have been impacting on changes in pest abundance. If such models could be developed and validated, then they may be useful for modelling the impact of changes in the farming system (e.g. introduction of BGII). There may also be potential for application to other industries, regions. What do we have in the way of models, or capacity, that could be used in this process?
- HEAPS is not good with mortality prediction in its current form. There may now be better information that could be incorporated into HEAPS to improve its capacity in this area. Linking APSIM and HEAPS would create a farming systems based model (one of the potential outcomes of links between the new CRCs proposed- Cotton and Climate)
- Need economic data to really prove value of IPM and gain growers confidence in IPM

Conventional chemistry: insecticides and resistance

by Dr Robin Gunning NSW Ag Tamworth, Australian Cotton CRC

What work is being conducted?

Insecticide susceptibility baseline data for helioverpa is being generated.

Insecticide resistance monitoring of helioverpa populations on cotton and to some extent, on other crops.

Insecticide resistance mechanism studies, cross resistance and genetics.

Insecticide resistance management on cotton, pro-active strategies that are fine-tuned each year to prevent the development of resistance to new chemistry or ameliorate the effects of existing resistance problems. We are trying to promote resistance management on all host crops.

Why is this work being conducted – what are the issues?

Helioverpa armigera resistance to insecticides is a severe limitation to the economic production of cotton and other crops in Australia. Insecticides will continue to be necessary for the control of helioverpa in the foreseeable future.

Area-wide insecticide resistance management strategies are vital for the prevention or limitation of the development of insecticide resistance in helioverpa.

Who are the key workers in this area?

NSW Agriculture - Louise Rossiter, Marje Balfe and Robin Gunning
Robin's collaborators from Rothamsted Research, UK- Graham Moores, Susan Young and Georgina Bingham
University of Sydney - Alan Clift
Agriculture Victoria - Peter Ridland and Deanne Glenn

What are the key findings and their implications?

Helicoverpa armigera has developed resistance to almost all insecticides used against them and it is essential that we practice pre-emptive resistance management. This can only be achieved by resistance monitoring and an understanding of the mechanisms, genetics and cross-resistance implications of resistance.

We have developed a good understanding of *H. armigera* resistance and are using these data in scientifically based resistance management strategies.

What are the bigger picture outcomes? How would you quantify and measure these?

We are looking at smarter, faster and less labour intensive ways to monitor for insecticide resistance. Our resistance mechanism studies have enabled the development of biochemical resistance detection and we are doing the same thing with molecular methods.

What are the major challenges in this area of work?

Preventing over exposure of new insecticides.

Managing resistance while practicing IPM. IPM has led to the overuse of some insecticides and a whole new class of resistance problems in *H. armigera*.

Area-wide adoption of resistance management (all industries, not just cotton).

Funding - the cotton industry pays whilst other growers of crops benefit.

Where do you see this work going in the future?

H. armigera will continue to develop resistance to everything that we throw at it, there will always be new resistances to study.

Bollgard®II cotton is not going to solve insecticide resistance problems.

Major research to overcome resistance to older chemistry is a very worthwhile area of research.

Discussion

- Resistance widespread
- Rate of resistance development to new insecticides is not slowing down. What have growers/consultants/industry really learnt about managing insecticide resistance? Are we really managing resistance if we continue to get resistance to new products within a season or two of them being available for use?
- IRM is supported by IPM and vice-versa but is IPM encouraging heavier use of new chemistries?
- Are we progressing with resistance management in production systems?
 - Chemicals get used
 - Chemicals not released strategically but sequentially as available
 - People always will want a silver bullet/easy answer
- Chemical companies frustrated at not being included in development of resistance management strategies. Resistance management is regularly in conflict with the market opportunities identified by chemical companies.
- Cross-resistance explains some resistance to new chemistries
- Population concentrations at specific times of the season can result in intense selection of populations from a single application
- Need to be able to put a monetary value on resistance

Biopesticides and resistance

by **Caroline Hauxwell DPI&F Brisbane, Australian Cotton CRC**

What work is being conducted?

The development of microbes as management tools for invertebrate pests, specifically the use of nucleopolyhedroviruses (NPVs) and Deuteromycete fungi (Metarhizium, Beauveria & Nomuraea). This includes projects on:

- The development of additives and application methods for enhanced performance of NPVs
- Establishment of baseline susceptibility data and methods for monitoring of resistance to NPVs
- Selection, production and quality control of new NPV products (with commercial partners)
- Development of mycoinsecticides for emerging pests (mirids, whitefly, GVB, aphids) and integration into IPM
- Development of improved and novel production technology for fungi.
- Evaluation of attitudes to risk and use of IPM.

Why is this work being conducted – what are the issues?

Biopesticides provide an effective and 'soft' alternative to chemical insecticides, and work especially well as tools in an IPM strategy that seeks to avoid generation of resistance and to maintain populations of beneficial insects.

Research on additives and delivery methods of NPVs seeks to improve the reliability and efficacy of NPVs, particularly in cotton.

Resistance monitoring is to address industry concerns on perceived risk of emergent resistance. Work on new NPV products addresses manufacturers demand for new, improved and reliable products.

Mycoinsecticides are being developed for sucking pests (not susceptible to NPVs) that threaten existing IPM by requiring use of hard chemistry. Improved production technology aims to make them available and cost effective.

Assessment of attitudes to risk and IPM are essential to extension and improved grower uptake of technology.

Who are the key workers in this area?

In broadacre crops, the QDPI&F biopesticide unit consist of :

Carrie Hauxwell - team leader and active researcher on NPV production, formulation and application, and on mycoinsecticides.

Andrew Reeson - NPV additives and evaluation of attitudes to risk and IPM

Dave Holdom - Mycoinsecticides and their production technology.

Kristen Knight and Damien Cupitt - Mycoinsecticides of sucking pests.

Karen Boundy, Jacinta McMahon and, until recently, Alexandra Glauerdt - NPV resistance monitoring and technical support across projects.

What are the key findings and their implications?

Some (but not all) commercial additives (eg. AminoFeed) enhance performance.

Some novel additives improve performance on cotton.

ULV application with oils significantly increases efficacy on plant.

Resistance to NPVs is not evident and is unlikely to emerge in helicoverpa.

New NPV products have and will continue to become more widely available.

Mycoinsecticides have demonstrated (proven) efficacy against mirids, have potential against GVB and may be useful against aphids with further work on formulation.

There is significant potential to improve yield and range of producible mycoinsecticides

What are the bigger picture outcomes? How would you quantify and measure these?

NPVs have been widely adopted for helicoverpa (judged by sales). Two NPV products are now registered, and more are expected. A local NPV production company has been established.

Use of additives (especially AminoFeed and similar), ULV and oil formulations are used but should be widely promoted as best practice.

Perceived risks of resistance should not be allowed to prevent optimal use of NPVs, including frequent application at reduced rates IF EFFECTIVE.

Mycoinsecticides have real potential (judged by efficacy in field trials, impact on natural enemies and production characteristics)

We are evaluating perceptions of risk and adoption.

What are the major challenges in this area of work?

Finding enough *Helicoverpa* sites for field data - we've resorted to foliar assays in recent years.

Integrating mycoinsecticides with models of pest population data.

Increasing grower adoption and overcoming perceived risks of yield loss.

Establishing commercial production, quality control and marketing.

Where do you see this work going in the future?

Development of mycoinsecticide control and population and damage models for mirids and GVBs, Registration and integration into IPM of mycoinsecticides and development of decision tools based on population and damage data.

Greater understanding of impacts of mycoinsecticides on pest ecology and beneficial insects.

Improved formulation of mycoinsecticides for aphids and whitefly.

Improved extension tools and industry adoption of mycoinsecticides.

Detailed studies on NPV strain variation and population biology.

Development of biopesticides against remaining tractable broadacre targets - DBM, mites, thrips.

Role of wider microbial / insect interactions in pest ecology and management

Discussion

- ULV allows the use of higher concentration of additives (e.g. Amino-Feed, spray oils). The use of additives has significant advantages in relation to the efficacy of NPV.

Bt resistance in *Helicoverpa armigera*

by Rod Mahon CSIRO Canberra, Australian Cotton CRC

What work is being conducted?

1. Monitoring levels of resistance to Cry toxins in field populations of *H. armigera* and *H. punctigera*.
2. Genetics of resistance to Cry toxins in *Helicoverpa armigera*.
3. Fitness costs associated with two forms of resistance to Cry toxins.
4. Determine the mechanisms associated with Cry2Ab resistance in *Helicoverpa armigera*.
5. Characterise newly isolated colonies resistant to Cry2Ab in order to assess the likely impact on the longevity of Bollgard®II.
6. Assess opportunities for selection for the BX form of resistance to Cry1Ac in Ingard.

Why is this work being conducted – what are the issues?

1. Monitoring resistance to Cry toxins in field populations of *H. armigera* and *H. punctigera*
Monitoring for resistance to Bt toxins began with the introduction of Ingard. Two tests were conducted; one to detect resistance to Cry1Ac (using the formulated product MVP), and the other to detect resistance to all Cry toxins (using Dipel, that contains a variety of Cry toxins). The monitoring program is evolving to replace MVP with a more defined source of Cry1Ac. We are also developing methodologies, and will introduce in 2005 screening methods for Cry2Ab resistance. In the 2003-04 season, an additional technique was evaluated, namely F2 analyses that are capable of detecting recessive forms of resistance.

2. Genetics of resistance to Cry toxins

This work is a collaborative one between CSIRO Entomology and Dr David Heckel, University of Melbourne. The objective is to identify the gene(s) associated with resistance in *H. armigera* to

Cry1Ac (BX line) and SP 15, our new Cry2Ab resistant colony. The genetic basis of resistance to a large extent determines the rate of evolution of resistance in field populations. In addition, pursuing and identifying the actual gene(s) that confer resistance may lead to a simple tool to score frequencies of 'resistant alleles'.

3. Fitness costs associated with the two Cry resistance genes

Rationale of this research. In the absence of selection, the frequency of a mutation that confers resistance is a balance between the mutation rate and any fitness cost associated with the mutation. In the presence of selection, the rate of increase in a gene that confers resistance to the selective agent is determined by a combination of the selection pressure and the fitness of resistant genotypes. If the loss of fitness associated with possessing the resistance is high, the rate of increase in resistance will be low regardless of the intensity of selection. We are exploring fitness cost associated with resistance to Cry1Ac and Cry2Ab individually and together if it is possible to construct a doubly resistant line.

4. Determine the mechanisms associated with Cry2Ab

Insects may evolve resistance to Cry toxins through various routes. For example, the BX form of resistance in *H. armigera* occurs through a failure of the Cry1Ac molecule to bind to receptors in the gut of the larvae. Similar mechanisms have been found in other Lepidoptera. The resistance mechanism to Cry2Ab is as yet unknown.

5. Determine the characteristics of the new Cry2Ab resistance

Various factors determine the potential threat posed to the longevity of Bollgard®II by the recently discovered allele that confers resistance to Cry2Ab. The characteristics of most interest are the frequency of the allele, its dominance and, the extent that resistant genotypes can withstand high concentrations of the toxin. Each of the above factors is presently being examined.

6. Opportunities for selection for the BX form of resistance to Cry1Ac in Ingard

The BX form of resistance was isolated by laboratory selection of field populations of *H. armigera* in 1998. However it has failed to become widespread despite the deployment of Ingard for seven cotton seasons. This study has examined the survival of resistant genotypes on Ingard cotton throughout the growing season in order to assess the extent and the duration of advantage they experienced relative to susceptible genotypes. This work is ending with the removal of Ingard.

Who are the key workers in this area?

Rod Mahon, Ray Akhurst, Sharon Downes, (CSIRO Entomology), and David Heckel, (University of Melbourne, and Max Planck Institute).

What are the key findings and their implications?

The major focus of our current research is the colony resistant to Cry 2Ab found in 2002-03. While evaluating a new monitoring technique, we isolated one allele (out of 132 examined) that conferred a >1000 fold resistance to Cry2Ab relative to susceptible alleles. The relatively high frequency of the allele in the sample ($1/132 = 0.007$) was itself surprising, especially as Bollgard®II and therefore Cry2Ab had not yet been deployed in the field.

What are the bigger picture outcomes? How would you quantify and measure these?

Bollgard®II represents a unique opportunity for the cotton industry to control helioverpa without the use of conventional insecticides. Retention of the susceptibility of *H. armigera* and *H. punctigera* to Cry toxins will yield significant benefits to the industry through savings on insecticides and their application. There will also be a considerable environmental benefit through reduction of the use of insecticides

What are the major challenges in this area of work?

The development of appropriate resistance management strategies to maintain the susceptibility of field populations of *H. armigera* to Bollgard®II. This will be facilitated through an appropriate monitoring of field populations and an understanding of the genetics, population genetics and physical characteristics of resistance alleles present in field populations of the pest.

Where do you see this work going in the future?

Improving our ability to detect resistance alleles when at very low frequencies will improve our means to 'manage' the development of resistance. Hopefully Bollgard®II will be effective for many years. Alternative transgenic crops are likely to become available in the future, and these too will present resistance management challenges that again will rely on basic research on the genetics and population genetics of resistance.

Discussion

- Feeding habits of susceptibles
- Collaboration planned for two labs
- Traditional resistance management still needed
- Cry 2 mechanism being worked on, as is fitness cost of homozygous resistant
- Cry IAc expression needs more work
- Is 10% refuge a valid assumption?

Session 3

Increasing effectiveness of parasitoids and predators of *helicoverpa*

by Peter Ridland DPI Knoxfield

What work is being conducted?

In their comprehensive review of beneficial organisms in cotton farming systems, Johnson et al. (2000) provided a detailed overview of the considerable Australian research effort directed at beneficial organisms (estimated at \$20-\$25 million since 1990) and highlighted the future challenges for effective use of natural enemies within integrated pest management systems. Apart from the large amount of funding (approx. \$12 million) from cotton and grains, there has also been considerable investment in use of natural enemies in *helicoverpa* management in horticultural industries, particularly in sweet corn and tomatoes.

This summary is focussing on research on parasitoids and predators. Major areas of work currently being undertaken in Australia include:

1. Impact of new insecticide chemistries on natural enemies and the integration of this information into recommendations for growers and consultants.
2. Role of generalist predator assemblages e.g. spiders, ants.
3. Abundance of predators and parasitoids in Bollgard®II cotton.
4. Autecology of individual predator species e.g. damsel bugs and assassin bugs.
5. Potential for augmentative release of assassin bugs.
6. Habitat manipulation to provide refuges for conservation of beneficial arthropods.
7. Use of supplementary food sprays to increase abundance of predatory insects.
8. Movement of natural enemies into and between crops.
9. Role of larval parasitoids.
10. Augmentative releases of *Trichogramma*.

There has been a major effort in many industries to raise awareness of natural enemies amongst growers. Many excellent illustrated guides have been produced for industries such as cotton, lettuce, tomato and sweet corn. In most cases, workshops have also been held to assist growers get 'hands-on' experience in identifying natural enemies as well as pests.

Why is this work being conducted – what are the issues?

In the last decade, interest in the role of natural enemies has been accentuated by events such as the frustrations of insecticide resistance being experienced by a wider range of industries, the availability of a number of new insecticide chemistries with reduced toxicity to many natural enemies, the advent of transgenic crops, the increased efforts in implementing area-wide management for *helicoverpa*, the

establishment of *Trichogramma pretiosum* in Queensland and NSW, the availability of the biopesticide, Gemstar® and the greater use of *Bacillus thuringiensis* in horticultural crops. “Most of us agree that natural enemies are important, but we struggle to quantify their contributions in the ‘real world’ of pest management decision-making, and our ability to sell it to consultants.” Dave Murray (personal communication).

“Bollgard®II cotton will be a major component of agricultural landscapes in cotton farming areas and we need to know what effect B.t. cotton will have on natural enemy abundance – not just for *Helicoverpa* management, but for other pests as well (e.g. mirids, aphids, whiteflies). There will also continue to be a conventional cotton component of landscapes, so we still need to evaluate sustainable ways of managing *Heliothis* in conventional cotton.” Brad Scholz (personal communication)

“The assassin bug might have significant potential as an applied biological control to fulfil a niche for the control of caterpillar pests in cotton and other crops. Currently biocontrol for *Helicoverpa* has been biased towards egg parasitoids which leaves few augmentation options for targeting larvae. We also thought that a generalist predator that has preferences for larval prey had some advantages over host-specific natural enemies particularly in cotton where *Helicoverpa* is an intermittent/recurring pest that can be absent for several weeks before re-appearing. Many host specific larval parasites do not persist well in cotton due to the lack of host continuity whereas a generalist predator can switch prey and survive.” (Paul Grundy, personal communication).

Who are the key workers in this area?

This list includes most researchers who have had a major involvement in natural enemies in the past few years.

Queensland QDPI&F broadacre cropping - Dave Murray, Brad Scholz, Melina Miles and Paul Grundy
horticulture - Iain Kay, John Duff, John Brown

University of Queensland Myron Zalucki, Marie-Louise Johnson, Sarina Pearce, Andrew Davies, Mark Wade (now at Lincoln University)

BioResources Pty Ltd Richard Llewellyn

NSW CSIRO Entomology cotton - Martin Dillon, Mary Whitehouse, Sarah Mansfield

NSW Agriculture cotton - Robert Mensah, horticulture - Sandra McDougall

University of New England Peter Gregg, Tish Silberbauer (now at Macquarie University), Rob Annetts (now with Dow), Ingrid Rencken

University of Sydney, Orange Geoff Gurr, Z. Hossain

Victoria CESAR, La Trobe University Horticulture – Ary Hoffmann, Swarna Hewa-Kapuge (Trichogramma studies)

South Australia SARDI Nancy Schellhorn (field movement of *Plutella* parasitoids; techniques applicable to *Helicoverpa* studies)

Adelaide University Mike Keller (molecular detection of prey; floral resources for parasitoids [*Plutella*])
New Zealand

Crop and Food Research, Auckland Graham Walker (larval parasitoids - successful establishment of *Cotesia kazak* and *Microplitis croceipes* for control of *H. armigera*)

What are the key findings and their implications?

Trichogramma pretiosum is now well established in SE Queensland and parts of NSW. Rather than needing augmentative releases, natural populations can lead to high levels of egg parasitism when linked with selective insecticides. Provided consultants are rapidly made aware of levels of egg parasitism, effective control can be achieved. A similar situation exists in the processing tomato industry in Victoria where consultants assess parasitism level of eggs after sampling and have modified the control threshold to account for the parasitism.

Predator assemblages observed in cotton tend to peak in abundance relatively early in the season and then fall away as the season progresses. Inherently, the predatory fauna is variable spatially and temporally as well as in species composition. In contrast, populations of undisrupted egg parasitoids continue to build up during the season. The resistance management strategy of selective insecticides early with broad-spectrum insecticides later in the season is more in tune with conserving predators than parasitoids.

Spiders have been shown to be very abundant in all cropping systems and so will be feeding on a wide range of arthropods (pests, non-target and beneficial). In Australia, many spiders are still undescribed and much work remains to be done to determine the most important predators of pest

arthropods and how their activity can be enhanced. However, the assemblage of spider species undoubtedly plays an important role in regulating other arthropods, particularly at the time of colonisation.

Based on field experiments and experiences, a beneficial disruption index (BDI) has been calculated for the insecticides registered for use in cotton. This index has been widely extended to growers. The concept is being adapted for use in other industries.

What are the bigger picture outcomes? How would you quantify and measure these?

The role of generalist predators in all cropping systems in Australia remains largely undocumented and probably unappreciated. All too frequently, numbers of potential predators are estimated from crop sampling and it is then assumed that their abundance is directly related to impact. At present, the promotion of natural enemies in IPM programs is essentially passive, relying on the use of more selective insecticides. While predator/prey ratios have been promoted to guide growers and consultants, these figures still are difficult to relate to the actual impact of natural enemies. Estimating total numbers of potential predators using biased sampling methods can only ever be a first step in the goal of effectively manipulating natural enemies.

It will be important to continue comparing the economic return of areas managed to conserve and encourage natural enemies (through IPM techniques) with areas managed with little regard to the natural enemy community. Growers are gaining some confidence in natural enemies, but will need reinforcement with such studies.

If area-wide management is to be successfully implemented, we need much better information on movement of pests and natural enemies between crops and non-cropping areas.

What are the major challenges in this area of work?

The key research tasks Johnson et al. (2000) listed for increasing the abundance and effectiveness of the main predators and parasitoids remain relevant today. Until this can be done, it will be very difficult for growers and consultants to effectively utilise information about natural enemies in their decision making.

1. Basic biological and ecological knowledge of individual species is needed before key species can be managed effectively. Of critical importance is learning how individual predatory species find prey in a field situation on different crop plants.
2. Knowledge of distribution and movement in and between cotton, other crops and natural vegetation is needed to address ways of minimising the lag time / recolonization events of natural enemies, both in the spring and from non-sprayed on-farm refugia into the crop. Studies of their overwintering habitat, and the arrangement of early- and mid-season rotation crops as a way to build up populations of natural enemies are also needed. Direct measurements of movement are needed if we are to manage populations effectively on a landscape scale. We cannot just rely on correlations between natural enemies and pests. Improved sampling schemes are needed to give more accurate estimates of predator density (we need to ensure that all relevant guilds of predators and parasitoids are sampled).
3. Understanding the impact of beneficial arthropods on pest populations. Molecular and immunological techniques are being developed overseas to quantify the amount of prey in predators' guts are still in their infancy in Australia. As well, complementary field observations and prey consumption trials are needed. This work will be time-consuming and difficult, but essential.
4. Further understanding of the effects of pesticides on beneficials. Indirect as well as direct effects need to be assessed in a repeatable way.
5. Improved decision support tools for using beneficial insects are needed to enable mortality from natural enemies to be formally incorporated into decision making for pest control.

Where do you see this work going in the future?

The research required to predict impact of individual predatory species will be inherently difficult and laborious. In recent years, graduate students have undertaken much of this work. It will be essential to provide continuity of funding to ensure that research groups remain intact and that graduate students can continue to build on their experiences in post-doctoral programs.

It should be emphasised that the issues relating to assessing the impact of natural enemies are not specific to helioverpa and would be relevant to a wide range of cropping situations.

Reference:

Johnson M.L., Pearce S., Wade M., Davies A., Silberbauer L., Gregg P. and Zalucki M.P. (2000) A Review of Beneficials in Australian Cotton Farming Systems. Report for the Cotton Research and Development Corporation.

Acknowledgments:

I thank Nancy Schellhorn, Sarina Pearce, Tish Silberbauer, Brad Scholz, Richard Llewellyn and Dave Murray for their responses to my questions about their work with natural enemies.

Discussion

- Can we be more proactive in regard to the conservation or augmentation of natural enemies? – For example, what is the contribution of remnant vegetation and revegetated areas?
- Are there funding opportunities through environmental dollars e.g. catchment groups
- Growers are asking for information on the suitability of different plant species, used in revegetation projects, to provide habitat for, or enhance the contribution of, beneficials
- There are still significant gaps in our knowledge, and this influences confidence in IPM. For example, What factors affect huge natural variations in natural enemy populations? Where do they come from?
- In February/March 2004, there were recorded levels of *Trichogramma* parasitism up to 90% on Darling Downs. In these fields there were no sprays applied to egg lays of 50 eggs/m. This result is spectacular in the context of what the response to a 50 egg/m event would have been in the past. If *Trichogramma* monitoring wasn't being done, there would have been sprays applied.
- Limited knowledge of where *T. pretiosum* is established – need a more systematic approach to establishing it in certain districts
- Low egg viability (*H. punctigera*) in 2003/04 season – not all attributable to parasitism. Maybe super-parasitism? Bug attacks? Egg dumping due to poisoning? Unmated eggs?
- Need to encourage consultants to collect information on natural enemies (eg. charge for monitoring parasitism). Consultants and growers need to develop an understanding of what is going on in their fields to develop confidence in IPM.

Forecasting population outbreaks of helioverpa: an impossible dream?

by Meron Zalucki University of Queensland Brisbane

What work is being conducted?

At the moment very little. We are currently analysing an extended series of light trap data from Narrabri to test regression based models that were developed from a limited data set (earlier work is all published). Developing and testing the use of spatially derived climate based models to predict temporal variability in insect abundance.

Work in inland source areas for migrants has pretty much ended except on an ad hoc basis

Why is this work being conducted – what are the issues?

Fundamental issue remains whether we can make reliable "real" forecasts of helioverpa abundance on an area wide (regional) basis that will be of use to pest managers. The alternative use of this research is in interpreting long term changes in abundance (pest pressure) in relation to management strategies. Among the crucial questions this work will enable us to address: Is helioverpa declining in abundance due to changing crop type (transgenics), climate or AWM?

Other issues are the usual suspects: time, money (co-ordinated industry support), availability of long term data, co-operation amongst the player.

Who are the key workers in this area?

Myron Zalucki, Derek Maelzer, Mike Furlong
Peter Gregg, Alistair Drake, Gary Fitt, David Murray

In fact any one interested in Area Wide Management and the species ecology (that is any one who can see beyond the horizon and is not bogged down in one field of a particular crop!)

Full summary paper not available

Discussion

- Lack long term data sets (funding)
- What data could be sourced from old projects?

DNA applications (microsatellites for migration, helicoverpa diagnostics and other research)

by Dr Kirsten Scott University of Queensland Brisbane

What work is being conducted?

Microsatellites for Migration:

Over the past four years the microsatellite project has evaluated the quantity and direction of *H. armigera* moth movement over 12 major cotton and grain growing regions. Since June 2003 the project has also begun incorporating *H. armigera* bioassayed for insecticide resistance (by Louise Rossiter). This is now providing detailed information on the occurrence, speed and direction of movement of resistance in *H. armigera*.

Why is this work being conducted – what are the issues?

H. armigera is still an important insect pest to field crops in Australia, and the establishment of AWM and IPM strategies has been critical in successfully managing this pest. Effective AWM and IPM are knowledge intensive; they require a clear understanding of the agroecosystem, especially the pest biology and genetics. Recent advances in molecular biology and population genetics provide the opportunity to accurately assess the migration and recruitment of pest populations. The additional incorporation of bioassayed material in the current project is now allows us to "source" resistant and susceptible moths each season - further enabling the refinement of management strategies for *H. armigera*.

Who are the key workers in this area?

Primary research conducted by Dr Kirsten Scott, Dr Nicole Lawrence and Corinna Lange with support from Leon Scott, Glenn Graham, David Murray, Melina Miles, Louise Rossiter, Phil Armytage - CGS, Brad Scholz, Peter Gregg, Paul Grundy, Martin Dillon, Scott Hardwick, David Kelly, Hugh Brier, Carrie Hauxwell, Joanne Dawson, Cathy Mansfield, Iain Kay, Julie O'Halloran, Robert Dimsey, Ian Crosthwaite, Annie Spora, Annie Sullivan, Ingrid Christiansen, Macpherson Ag., Ag. Street Services, Andrew Ward and many others.

What are the key findings and their implications?

1. The genetic data supports the rationale for the current area-wide management strategies for *H. armigera* by demonstrating that *H. armigera* can be 'local', and is therefore likely to be influenced by local population management practices (eg. in 2002-2003). However, regional or Australia-wide approaches need to remain co-ordinated to manage this pest in years with high levels of migration (eg.2001-2002).
2. The research is enabling us to show specifically where migrating populations come from and when migration occurs at both the local and regional levels. (details of specific local events are given in several recent publications).
3. Data are now indicating that selection as a result of environment and management is playing a very significant role in the genetic structuring of populations
4. This year we have begun monitoring the movement of known insecticide resistant/susceptible individuals (material bioassayed by Louise Rossiter). This should provide a detailed picture of the importance of "sources" to the management of resistance in *H. armigera*

What are the bigger picture outcomes? How would you quantify and measure these?

This study has provided a detailed understanding of the fundamental biology and genetics of *Heliothis* in Australia. The analysis of local population structure, recruitment within a local area and migration between regions are key to understanding the development, spread and persistence of resistance. This study provides high-resolution information on the population structures of *H. armigera* at local, regional and national levels. This is important to ensure that AWM strategies are based on a sound understanding of the biology and genetics of *Helicoverpa* and that the results of AWM can be reasonably interpreted. A key challenge to undertaking a project on this scale is interpreting the large amounts of data in relation to local management issues. We have, and will continue to, rely heavily of local collaborators to present our findings in a sensible manner.

What are the major challenges in this area of work?

The major challenges for this research are the maintenance of the broad sampling strategy, and having the funds to sustain research staff.

Where do you see this work going in the future?

I would like to see the technology and approaches which have been developed in *Helicoverpa armigera* applied to other pests, perhaps green vegetable bug, *Bemisia* or mirids, as it provides both basic movement information along with specific information for management ie. movement and spread of resistance.

We are also trying to look at alternative funding sources to undertake equivalent research for *H.punctigera*.

Discussion

- Long-term data important to understand migration versus 'stay-at-home' years and reasons
- Willing to analyse data from other regions – who has some?
- Could use these techniques to assess effectiveness of refuges and map moth movement in and out of refuge areas

Semiochemical approaches to management of *Helicoverpa* **by Peter Gregg University of New England Armidale, Australian Cotton CRC**

What work is being conducted?

Semiochemicals are chemicals which influence insect behaviour. There are three main groups which might be of use in *Helicoverpa* management. They are pheromones, kairomones (food lures) and substances which repel or deter oviposition or larval feeding.

The pheromones of *Helicoverpa* are well characterised and are available in lures which have been used for monitoring. While they can give a broad picture of the presence and abundance of *Helicoverpa*, pheromone trap catches are not well correlated with oviposition and cannot be used to time control measures. Attempts to use pheromones in mating disruption have been frustrated by the mobility of mated female moths. I will describe a recent experiment in which we attempted to disrupt mating on 100 ha of tomatoes near Bundaberg. Attract-and-kill for male moths using pheromones remains a possibility, however.

Kairomones offer more promise in attract-and-kill because they attract female moths as well as males. We have developed a synthetic blend of plant volatile compounds which were shown to be attractive to both sexes of *H. armigera* in the laboratory. It is formulated with a feeding stimulant (sucrose) and an insecticide. We have reached the stage of commercial field trials under a Product Evaluation Permit from APVMA. About 13,000 ha of cotton were treated in the 2003/04 season. This product (Magnet®) is being commercialised by Ag Biotech Australia Pty Ltd, who are seeking registration for it in 2005. Magnet® has effects beyond the field in which it is sprayed, and we see such products as valuable tools in area-wide management.

Research on antifeedants and oviposition deterrents is at a more fundamental stage, but progress has been made in Cotton CRC research in DPI&F and NSWAg on identifying the chemicals responsible for these effects in some cotton varieties, and in a native cotton species. These semiochemicals, perhaps in combination with attractants, may eventually give us wide-ranging abilities to manipulate the behaviour of *Helicoverpa*.

Why is this work being conducted – what are the issues?

We need alternatives to insecticides for *Helicoverpa* management (beyond transgenic plants and beneficial insects), to contribute to IPM and AWM, and semiochemicals provide one such possibility. New techniques in analytical chemistry and insect physiology are enabling us to pinpoint the types of semiochemicals which may be most useful.

Who are the key workers in this area?

Pheromones: Peter Gregg and Alice Del Socorro, UNE

Plant volatile attractants: Peter Gregg and Alice Del Socorro, UNE, Anthony Hawes, Ag Biotech, Stephen Sexton, Bioglobal

Antifeedants and oviposition deterrents: Robert Mensah, NSW Ag, Gary Fitt and Cheryl Mares, CSIRO

Organic chemistry: Chris Moore and Ertong Wang, QDPI&F

Insect behaviour: Paul Cunningham and Myron Zalucki, UQ

Many of these workers are included in a group sponsored by the Cotton CRC known as the Semiochemical Working Group

What are the key findings and their implications?

There are short-term commercial possibilities for plant volatile-based attractants for adult *Helicoverpa* to make a significant contribution to AWM in cotton and possibly other crops, with consequent reductions in insecticide use. In the longer term, antifeedants and repellents might also be useful, and with attractants might form a complex to use in manipulating *Helicoverpa* populations in cropping landscapes.

Mating disruption with pheromones appears unlikely to be economically practical, due to the ability of *Helicoverpa* to mate away from host crops, and for mated females to then move back into the crops. Attract-and-kill for males may offer some possibilities, especially if combined with female-attracting plant volatiles.

What are the bigger picture outcomes? How would you quantify and measure these?

The bigger picture outcomes include an improved arsenal of IPM and AWM techniques, the outcomes of which could be measured by reductions in insecticide use. There are also significant opportunities for Australian companies, especially small-medium enterprises, to develop national and international markets in semiochemical products.

What are the major challenges in this area of work?

There are few precedents for regulating semiochemical-based products for crop protection in Australia or internationally (with the exception of pheromones), so the attitudes of regulatory authorities on matters such as toxicology and residues will be critical in determining the feasibility of commercialising semiochemicals.

Grower attitudes will also be important. Magnet® has been positively received by cotton growers, but a shift in expectations is necessary – these products generally lower pest pressure over a region, they do not necessarily provide strong protection for the individual fields to which they are applied. There are also some technical issues to be resolved. These include rain-fastness (difficult for a product which must be ingested), and the choice of insecticide. The latter will be influenced by considerations of softness for beneficials and resistance management, and there is little information on these factors for insecticides included in attract-and-kill formulations targeted against adults.

For antifeedants and oviposition deterrents, a critical element will be the commercial availability of the chemicals, and their price. Some of them are quite complex and will be difficult to synthesise. Others may have limited stability.

Where do you see this work going in the future?

We expect to see a number of products similar to Magnet® on the market in the short-medium term. They will have activity against insects other than *Helicoverpa* and will be available in crops other than cotton. We are currently working on blends which attract green mirids.

Increasing use of transgenic resistant varieties, especially in cotton, is likely to reduce the potential market for semiochemicals targeted against *Helicoverpa*. However, there may be applications for these materials in resistance management for the transgenics. In some situations, attractants like Magnet® might be used to provide a chemical equivalent of pupae-busting (“moth-busting”). Another potential application is the use of these substances in conjunction with trap crops or refuge crops in resistance management. For instance, if applying attractants without insecticide resulted in increased oviposition on refuge crops, the area of the latter, which is required to produce an effective population of susceptible moths, could be reduced. We will soon be conducting experiments to find out whether oviposition can be increased in this way.

Discussion

- Magnet attracted 60-70% females
- Don't know if predatory shield bugs were feeding on Magnet
- Moths only attracted when ready to feed
- Distance travelled depends on other food sources, normal flight lengths etc.
- Potential use in vegetables - low tolerance to pest pressure a problem
- Magnet effective 4-6 days – need repeat applications in refuges
- Aerial application will be necessary for successful AWM
- Doesn't work in chickpea trap crops
- Opportunities to change formulation to increase time of effectiveness for refuges
- Must avoid use of single/few chemicals for resistance management purposes. Magnet allows use of very low doses of chemicals for kill.
- Opportunities to use adult killing chemicals currently not used, or IGRs?

Session 4

Novel options

Petroleum spray oils

by Robert Mensah NSW Ag Narrabri, Australian Cotton CRC

Summary not available

Discussion

- Oils kills by suffocation so need very good coverage
- Both additive effect and synergism
- With NPV, oil has activation affect; also UV compound plays a part – mechanism?

Helicoverpa genomics

by Karl Gordon CSIRO Canberra

An international consortium is proposed to sequence the complete genome of *Helicoverpa armigera* and make these data available to the international research community.

The biology of this pest is characterized by polyphagy, high fecundity, an ability to survive in a wide range of climates and on many host plants, and the ability to evolve resistance to environmental

stresses that include many pesticidal agents. Genome data will provide a comprehensive basis for research and for monitoring and managing pest populations. It will enable the design of new management strategies to forestall resistance and protect valuable biological control agents like Bt. It will help researchers studying: the genes expressed in *H. armigera* caterpillars feeding on a range of plants, in order to augment natural host plant resistance through knowledge of the cellular and biochemical processes of insect adaptation to dietary toxins; the enzymes associated with resistance to and detoxification of insecticides; the use of genetic markers to study population mobility as a basis for area-wide management programs; the identification of genes involved in resistance to Bt. Functional genomics studies will identify new targets for pest control. Information on insect genes that are critical for midgut growth and development may be used to provide new, species-selective, tools that promise to control pests and to protect crops in a more environmentally-friendly manner. For example, RNAi-based approaches may be suitable for the inactivation of some genes. Others may be inhibited by expression of suitable control factors in transgenic plants. Some crop or trap plants may also be engineered to express novel or modified pathways that deliver secondary metabolites capable of inhibiting or disrupting insect midgut gene function.

Groups from the following organisations have shown interest in forming the consortium: Australia: University of Melbourne (CESAR); CSIRO Entomology; China: Academy of Sciences; Academy of Agricultural Sciences; agricultural universities; France: Institut National de la Recherche Agronomique; Genoscope; Germany: Max Planck Institute for Chemical Ecology; India: Council of Agricultural Research; agricultural universities; USA: National Human Genome Research Institute.

The total cost of the project is estimated at \$A 10 million. It is estimated that approx. half of this may be obtained within Australasia. The remaining funding required is being sought from government agencies and other public sources in the other countries listed above. Significant amounts have already been spent on work to prepare for this project, mainly in France; considerable work has also been done in Australia. Progress to date includes construction of a bacterial artificial chromosome (BAC) library that is being used for the first phase of the sequencing work (funded by INRA/Genoscope). Databases containing sequence portions (expressed sequence tags – ESTs) from thousands of genes are being assembled separately by groups in Australia, China and Germany; integration of these datasets will be facilitated by and greatly help the genome project.

Helicoverpa thresholds

By Hugh Brier QDPI&F Kingaroy

Summary not available

Discussion

- Thresholds need data from a range of crops
- Implications for AWM if allow higher thresholds in crop. That is, potential for contributions to the local population if allowing some larvae to go through because it is not economic to control them.

Helicoverpa extension: successes to 2004, changes in progress, and opportunities beyond

by Austin McLennan QDPI&F Pittsworth, Australian Cotton CRC

What work is being conducted?

I am defining helicoverpa extension in this context as: Intentional activities conducted with the aim of changing, improving and/or maintaining the human knowledge, attitudes, skills and aspirations relevant to achieving best practice helicoverpa management in Australian field crops (cotton & grains) and horticulture. The other issue that jumps out here is that there is a need to define what is meant by the term "best practice helicoverpa management." While it may be tempting to think that this is the province of Research alone, we need to remember the D/E components of RD&E are critical for clarifying the useful and achievable parameters for defining 'best' practice, as well as for defining progress towards it.

A list of recent and/or current helicoverpa-related extension programs or activities that fit the definition above:

AWM groups and related activities (now mainly cotton participation) - AWM group approach has been initiated over last few years in all cotton producing valleys. Not all AWM groups are still active, or active to the same extent, or active under the initial Heliothis AWM banner.

Individual "Stand alone" workshops and meetings, often with a focus on particular skills (e.g. How to monitor *Trichogramma*)

or presentations within bigger events (e.g. GRDC updates, CCA AGM etc.)

Accredited Grower short courses: Cotton IPM short course

Accredited courses for agronomists: Chickpea and Mungbean agronomist accreditation courses in northern GRDC region. Similar accreditation courses now in southern and western GRDC regions (with less insect management)

Tertiary Courses: Crop protection component of UNE Cotton Production Course (CRC funded). UNE Grain production course (GRDC funded) - helioverpa section yet to be included.

- Access to helioverpa researchers (expert presenters at many extension events, eg. GRDC Updates Horticulture: Extension component of Sweet Corn IPM project

Private 'extension' / consultants

Why is this work being conducted – what are the issues?

AWM approaches for helioverpa in grain and/or cotton growing areas were initiated in a response to severe helioverpa pressures and levels of insecticide resistance that were generated under the high reliance on insecticides as the sole method of helioverpa control. Among the initial stated aims were objectives to reduce the overall helioverpa *armigera* population so that alternatives to chemicals (more IPM/biological options) would have a better chance of being effective.

It was recognised that AWM approaches involving co-operative action would be necessary to manage a pest situation where the impacts of various pest management practices were impacting the ability to manage the pest in other parts of the farming system, i.e. grains generating problems for cotton and vice versa.

The scientific question still remains whether the AWM research and extension push has actually reduced the helioverpa population. However there is no doubt that the AWM processes of bringing together of researchers, growers, extension staff and consultants, and involving them in finding their own solutions to a crisis issue, developed into an effective vehicle for introducing new AWM and IPM concepts and practices to the farming system.

THREE MAIN TRENDS:

1. More activity in the north: *Helioverpa armigera* is more difficult to manage and is more of an issue in the cotton and northern grain regions, hence the greater level of extension activity in these areas than in the south and west.

2. More activity in cotton: Up until recently (with the introduction of Bolgard II) helioverpa has been regarded as the key pest, and its management one of the key factors impacting on the profitability of cotton, hence a more specific insect pest management extension focus in cotton.

3. Less extension activity in horticulture, especially the further south you go.

A lack of helioverpa AWM approaches within horti may be due to ecological factors and pest status in a region (e.g. pest species, origin, potential for AWM) and also marketing factors (growers in direct competition).

Who are the key workers in this area?

COTTON:

Key helioverpa researchers - Researchers continue to play a valuable extension role in providing the information for extension or in doing it themselves (e.g. through involvement as part of an AWM group, presentations at workshops, IPM short courses and other industry meetings.)

One IPM development extension officer (Austin McLennan) who is part of the 'Helioverpa management in Southern Qld' project team (with Dave Murray and Melina Miles)

National Cotton Extension Team: All IDOs but esp. Insect Focus Team (Dave Kelly, Bruce Pyke, Mark Hickman, Greg Kauter, Sandra Deutscher, Austin McLennan)

Cotton IPM short course co-ordinator (Mark Hickman)

UNE Cotton Production course lecturers and co-ordinator (John Stanley)

'Private' Extension role of other industry companies/organisations as they relate to helioverpa management, eg. seed companies, CCA

GRAINS:

Grains Agronomist Accreditation team - northern region (helicopterpa components): Dave Murray, Austin McLennan, Melina Miles (+ related contributions from other DPI&F researchers (e.g. Carrie Hauxwell, Hugh Brier) and others John Slatter (Pulse Aus), Mike Lucy (DPI&F) etc)

UNE Grains Production Course: Craig Birchell

Other agronomist accreditation courses (southern and western): ???

HORTICULTURE:

Less current extension activities in IPM and helicopterpa especially. Sweet Corn IPM project (Peter Deuter, DPI&F) has been a recent successful project.

What are the key findings and their implications?

AWM has been a useful vehicle for introducing new practices

However, original AWM groups are transforming, either into IPM groups (not just helicopterpa) or broader grower groups (not just insect pest management)

Is this success and, if so, how permanent is this success?

What are the bigger picture outcomes? How would you quantify and measure these?

Changes in Knowledge, Attitudes, Skills and Aspirations are all important and should be noted, as well as changes in actual practice.

What are the major challenges in this area of work?

In cotton: declining pest status of helicopterpa?

In cotton & grains generally: maintaining a strategic capability to address insect pest management issues (including helicopterpa) despite perceptions of a declining pest status, and therefore possibly less funding for R,D&E.

In horticulture: Determining if there are any real issues that need to be addressed via extension. Is current practice best practice? Is it sustainable?

Where do you see this work going in the future?

AWM approaches appear to be in a state of transition, with participation growers, for various reasons, wanting to go 'beyond AWM' and even beyond IPM. There has been a change in the way that research and extension work together that needs to be built upon, and not lost.

In some cases, AWM groups may cease for the right reason - i.e. they have achieved their objectives. Agronomist Accreditation courses (and their resulting networks) have become a very important extension/delivery tool for helicopterpa management. However, the human resources to sustain the quality of these courses will require some level of continued funding, even though the courses themselves are self-sustaining, funded by a combination of industry \$\$ support and user pays.

Discussion

- There is a major challenge in working out how to maintain the interest of growers and consultants in AWM and IPM, in the absence of a crisis that forces the issues to the fore
- There is a general sense that there is a commitment amongst growers to learning and improvement despite 'losing interest' in a non-crisis period. The drivers that focus grower interest have moved from the need to control the pest to profitability of IPM/AWM.
- There is lots of knowledge/material available from other industries/outside agriculture on groups and extension – relevant techniques
- Extension can help people to learn from their mistakes, e.g. whitefly approach
- Is there a realistic expectation that there will be another crisis?
In the event of another crisis, the maintenance of networks and process to deal with it will be valuable. This was demonstrated with the SLWF situation in Emerald, where the established

AWM networks and relationships (technical and extension) meant that the issues and processes for coping with that crisis were dealt with quickly.

- Our improved understanding of systems means we are less surprised by crisis provided we have strong networks in place.
- How will industry cope with the next crisis? Human nature means that people move on to other things.

Evaluation of area wide management

by Martin Dillon CSIRO Narrabri, , Australian Cotton CRC

What work is being conducted?

- Quantifying the impact of AWM on helioverpa and beneficial arthropod populations - a case study approach of AWM groups in the Macintyre and Namoi valleys.
- Evaluating the Macintyre Valley IPM based Insecticide Resistance Management Strategy for cotton
- Cultural control of key cotton pests in Central Queensland
- Helioverpa management in South Queensland farming systems
- Helioverpa management in Southern NSW farming systems

Why is this work being conducted – what are the issues?

Helioverpa must be managed on a landscape scale

Evaluation of AWM and regional management approaches is essential to determine the effectiveness of new approaches, and to collect information that can be used in extension and education to change grower practices.

Issues include:

- Evaluating the effect of AWM on the spatial ecology, movement and population dynamics of helioverpa (and likewise beneficial insects & spiders)
- Evaluating effectiveness of components of AWM
- Economic evaluation of AWM and benchmarking field level profitability
- Evaluating sociological aspects of AWM- what works well? what doesn't?
- Evaluating the role that AWM plays in changing grower practices

Who are the key workers in this area?

Given the highly mobile nature of helioverpa moths, everybody working on their ecology, genetics and management must grapple with regional and area-wide issues.

Key workers that have addressed the "evaluation" of AWM approaches include:

Dr Melina Miles (DPI&F, Toowoomba)

Dr Richard Sequiera (DPI&F, Emerald)

Dr Scott Hardwick / Dr Simon Duffield (CSIRO Entomology, Griffith)

Christine Richards (University of Sydney Postgraduate, Narrabri)

Martin Dillon (CSIRO Entomology, Narrabri)

Ziaul Hoque and Bob Farquharson (NSW Agriculture, Narrabri & Tamworth)

What are the key findings and their implications?

- Helioverpa is definitely a regional pest.
- Case studies suggest that AWM approaches can potentially suppress helioverpa populations, but quantitative controlled experimental results remain elusive.
- Case studies suggest growers participating in AWM are more aware of IPM options and the need for sustainable insect management.

What are the bigger picture outcomes? How would you quantify and measure these?

AWM provides a potentially rich conduit for grower education and increased confidence in IPM

Measuring this will require more sociological and economic research and more research into farmers' perceptions of risk.

What are the major challenges in this area of work?

Does AWM suppress helioverpa populations on a regional scale ?

Does AWM reduce the risk of insecticide resistance ?

Is AWM more profitable for individual farmers ?

How should AWM groups be best supported ?

Where do you see this work going in the future?

Everywhere.

Discussion

- Horticulture experiences very similar to cotton
- Long sets of data collection needed to answer the 'hard questions'
- Maturity and confidence leads towards 'deep end' IPM practices
- Evaluation methodologies – can't use 'controls', use other techniques including case studies, grower perspectives, etc.

Prioritisation of Themes

At the end of these presentations, participants were asked to fill in the voting form (Appendix B) to answer the following question:

“What is the relative importance of each topic for the future management of helioverpa?”

Participants were given 10 votes each to allocate however they wished. The more votes given to a topic, the more important they considered it to be. It was permissible to give all 10 votes to a single topic, or to spread votes around numerous topics.

Results and Interpretation of Voting

| Topic | Whole group (n = 42) | Cotton (n = 29) | Grain (n = 15) | Horti (n = 10) | NE Aust (n = 29) | S'ern Aust (n = 15) | SW Aust (n = 4) | NW Aust (n = 6) |
|-------------------------------|----------------------|-----------------|----------------|----------------|------------------|---------------------|-----------------|-----------------|
| Area Wide Management | 41 | 32 | 12 | 8 | 21 | 21* | 5 | 7 |
| Insecticides & Resistance | 51 | 33 | 17 | 19* | 35 | 21* | 8* | 10* |
| Biopesticides & Resistance | 36 | 18 | 13 | 12 | 26 | 7 | 1 | 3 |
| Transgenics & Resistance | 48 | 46* | 12 | 4 | 30 | 18 | 3 | 5 |
| Natural Enemies | 55* | 32 | 22 | 18 | 36 | 18 | 4 | 6 |
| Climate, M'ment & Forecasting | 35 | 28 | 12 | 6 | 19 | 19 | 3 | 5 |
| DNA Appns | 12 | 10 | 5 | 3 | 8 | 5 | 1 | 1 |
| Semio- chemicals | 36 | 25 | 11 | 8 | 24 | 14 | 4 | 6 |
| Novel Options | 10 | 5 | 4 | 4 | 5 | 5 | 2 | 4 |
| Extension & AWM | 55* | 34 | 23* | 13 | 49* | 9 | 2 | 4 |
| Evaluation | 35 | 25 | 13 | 4 | 30 | 11 | 4 | 6 |
| Other topic | 6 | 2 | 4 | 1 | 5 | 4 | 3 | 3 |

Numbers in bold represent high scoring categories in column.
Numbers with asterisk represent highest score in column.

Some points associated with the voting results compiled by Dr John Rogers.

- With 12 topics and 42 people voting, there were 420 votes in total, or an expected value of 35 votes/ topic. With a Chi-squared value of 93.1 (compared to the tabulated value of 19.7), it is clear that the group considers some topics more important than others.
- The topics rating highly (>50) were Extension & AWM, Natural Enemies, Insecticides & Resistance.
- The topics rating low (< 13) were Other, Novel Options, and DNA applications. The first 2 of these are not surprising as at the time of voting they were ill-defined entities, and so difficult to vote for. Group discussion on the 'DNA applications' topic made clear that the group distinguished between the rating given and the overall importance of DNA applications; it was

broadly understood that DNA applications underpinned a number of other topics that were more highly ranked, e.g. AWM, resistance.

- The 'Other Topic' item received (by far) the lowest number of votes. This suggests that all the important issues were represented among the other items, and that no topic of high importance for helioverpa management had been missed.
- Almost 90% of votes were votes of 1 or 2. Only 10.6% of scores were greater than 2, and less than 3% of values were greater than 3. That is, most people gave votes of 1 or 2 to a wide range of topics, with very few individuals feeling that individual topics were of overriding importance. The conclusion from this is that very few people thought that there was a 'silver bullet' answer to improved helioverpa management, but that a broad-based approach involving a wide diversity of tools was the way forward. This was also obvious from the discussion that occurred over the 2 days.
- The topics that received votes of 3 or greater were Extension & AWM, Natural Enemies, Insecticides & Resistance, Biopesticides & resistance, Transgenics & resistance, Climate, movement & forecasting, and Evaluation. All of these had articulate 'product champions' in the group, so this result is, perhaps, as expected.

Highlights from Day 1

Three participants were invited to capture their views of the highlights from a session of presentations given on Day 1. These were reported to the plenary group early on the second day to serve as a reminder and a stimulus for the workshop sessions to come.

Session 2

Area Wide Management, Insecticides & Resistance, Biopesticides & Resistance, Transgenics & Resistance by Rob Annetts

1. There has been a dramatic fall in chemical use
2. Better intentions of horticulture
3. Pest management is based on chemotherapy. More time is needed to develop confidence in natural enemies
4. AWM is a vehicle to push IPM and should not be considered its equivalent
5. The importance of resistance management was stressed
6. Best practices need to incorporate improved tools for IPM
7. Bollgard@II is not silver bullet
8. There is a need to increase Cry IAc expression levels
9. There are no so silver bullets

Session 3

Natural Enemies, Climate, Movement & Forecasting, DNA Applications, Semiochemicals by Matthew Holding

1. How far have we come? The key message is that we've come a long way!
2. There is a need to tie the benefits of AWM into valid economic data
3. Consultants need as much prediction as possible
4. Natural enemies – we need to communicate their benefits to growers
5. We need to know more about predator impacts on pests with respect to control decisions
6. DNA technologies will provide insights into problem sources (helicopterpa movement)
7. There are many tools, but the difficulty is how best to integrate them
8. There is likely to be a trend towards increasing horticulture into cotton/grains cropping systems

Session 4

Novel Options, Extension & AWM, Evaluation by John Slatter

1. Oils – we need to find their best fit and how to use them
2. Genomics studies will increase our understanding of the species and broaden applications
3. We need accurate thresholds and direction on how to use them - \$ value is important
4. In determining thresholds, we must include both yield and quality
5. Evaluation must have a planned approach
6. Evaluation must incorporate the economic benefits
7. Once the crisis is over, complacency sets in. How best can we handle complacency? We need the right hooks in message
8. High grower participation is critical
9. Cotton and pulses are now prepared for the helicopterpa challenge

Identifying Key Issues

Small groups worked on the selected topics using a pinboarding exercise. Participants considered the opportunities and constraints to improving helioverpa management. They were encouraged to think broadly, and even include ideas which were unrealistic at the moment. The constraints listed contained any 'unmentionable' problems, as well as current and foreseen constraints.

The question for this exercise was:

“What are the opportunities and constraints for this topic to improve helioverpa management nationally?”

The raw results of the pinboarding exercise are included in the Appendix C.

At the conclusion of the exercise, each group prioritised the issues raised in addressing the question above as High, Medium or Low in relation to the need for Research, Development and Extension in order to progress.

These issues are prioritised and outlined below, highlighting the key opportunities and constraints identified.

Priorities set through pinboarding exercise

H = High M = Medium L = Low

Area Wide Management

Building on existing knowledge and successes (Priority = High)

Opportunities exist to create linkages across industries, particularly where the same pest is being managed e.g. helioverpa, SLWF. There is potential to extend AWM to pests other than helioverpa. Constraining this may be differences in the attitudes and culture of the different industries, conflicting priorities, and a history of individualism amongst growers (e.g. vegetable growers).

The benefits of progressing AWM beyond its current application in the northern region, grains-cotton context were seen as significant. For example, benefits would accrue in relation to IPM, insecticide resistance management, networking by growers and grower education.

There are challenges to both the existing, and any new, AWM programs. Principally these are associated with gaining and maintaining interest amongst growers to manage pests when not in crisis (severe pest pressure and loss). Addressing these challenges requires the input of government extension staff, the enthusiasm of growers and an ongoing extension effort. There is a significant risk of complacency amongst growers when pest issues are not at a crisis level, and other issues are pressing e.g. drought, water.

Natural Enemies

Basic knowledge of natural enemies in IPM (Priority = High)

Current knowledge about all aspects of natural enemy biology and ecology is limited. Most significantly there is little knowledge of which species are, or are capable of, making a significant contribution to pest control. Other knowledge gaps identified were

- Appropriate sampling and monitoring techniques for research, and for growers/consultants
- The impact of new insecticides and additives (e.g. salt) on natural enemies
- The potential to manipulate the farming system to create nurseries and/or refuges for natural enemies (e.g. through the application of moth/host attractants)
- The impact of transgenic crops on natural enemies

Using naturally occurring populations of natural enemies (Priority = High)

The conservation and enhancement of naturally occurring populations of natural enemies is desirable (as opposed to rear and release). This approach would be viewed favourably by the community as 'green' and sustainable.

Economic analysis of natural enemy impact (Priority = High)

Economic analyses of the cost:benefit of using natural enemies in pest management would be of benefit in promoting IPM, and particularly the value of natural enemies. The analyses would enable a dollar value to be put on natural enemies, for consideration by growers/adopters. The skills to do these analyses need to be sought.

Funding and employment in the field of natural enemy research (Priority = High)

There is a benefit in forming a natural enemy working group to build collaboration amongst participants, and raise the general awareness of ongoing research in this field. Participants felt that because natural enemy research is not recognised as an established field of research in Australia, there are major challenges in maintaining research programs in this area.

Extension and industry participation (Priority = Medium)

There is a need for greater awareness and knowledge of natural enemies amongst growers and consultants/advisers. Whilst the AWM networks offer opportunities for educational activities, these do not exist in all areas. Horticulture faces additional challenges with the range of crops, and often very short growing seasons.

Area-wide management of natural enemies (Priority = Medium)

The potential to manage natural enemies on a landscape level is considered to be significant. Such an approach may involve:

- Manipulating the farming system to provide habitat, refugia and nurseries for natural enemies
- Enhancing the habitat value of revegetation projects, and consequently the ecosystem services of these areas

Limited basic knowledge of natural enemy ecology is a constraint to this area of research.

Commercial production of natural enemies (Priority = Low)

A number of species (e.g. *Trichogramma*, assassin bugs) lend themselves to mass rearing and release. This offers opportunities to use those species in area-wide releases. Current constraints are the lack of artificial diets for many species, and consequently the high cost of production – resulting in a limited range of species currently available commercially.

DNA-based diagnostic tools (Priority = Low)

There is a range of molecular tools that could be used in studying natural enemies, particularly in determining predator-prey relationships, and determining levels of infection (parasitism, disease). Further opportunity exists for field deployment of these diagnostics.

Classical biocontrol introductions (Priority =)

Constraints to this field of work are considerable, limiting it as a viable option.

Extension

Coordinating/integrating service delivery – linking across industries (Priority = High)

There was benefit seen in looking for opportunities to integrate/coordinate the extension effort across:

- Industries

- Organisations
- Sectors (public – private)
- Extension providers

Resourcing to maintain the extension services would be facilitated by this coordination, and by formal linkages across industries. The use of larger networks and user-pays services would maintain and protect the quality of the extension provided.

Packaging, re-packaging and new extension approaches (Priority = High)

There is a need for user-friendly information to be available to would-be adopters. The packaging of information needs to be responsive to the situation, and current for the industry. It may require re-packaging to stay relevant and connect with clients. It is important to take a proactive approach to developing and using new models of extension and knowledge management. There is a risk of being constrained by the extension status quo that exists currently within industries.

Evaluation

Valuing evaluation (Priority = High)

Evaluation, in all its forms, was seen as extremely important. Of highest priority was developing and across-the-board (from stakeholder to client/end user) understanding of the use of evaluation at each level. This understanding would then guide the evaluation approach for R,D&E, be it formative, summative or iterative.

Skills and processes for evaluation (Priority = High)

Within the existing networks of Helicopterpa R,D&E, there is limited expertise in evaluation. Building, or accessing, these skills is imperative to ensure that evaluation is within the scope of all projects. The involvement of social scientists in evaluating and understanding the drivers for change was seen as being as important as economic evaluation. Improved evaluation will enable achievements to be reported in the context of farm, region, industry etc – of benefit to researchers, extensionists and stakeholders.

Identify key areas for evaluation (Priority = High)

Benchmarking is an accepted form of evaluation, but is dependant on the ongoing collection of data to enable comparisons. The maintenance of key data sets needs to be supported, as do the skills to use the large data sets – modelling, database management.

Climate, Movement and Forecasting

Collection and accessibility of data (Priority = High)

An ability to forecast is dependant on the availability of long-term data sets. Whilst there are a number of data sets held by different organisations, many have not been long-term, nor have they been linked in a way that would allow analysis. Funding is needed to ensure the collection of appropriate data (meteorological, farm) and the infrastructure to maintain the data sets (e.g. web-based).

Forecasting and prediction (Priority = High)

The potential for forecasting and prediction on a local, regional and national level is large –for research and for field applications. New technologies, advances in climate modelling and DNA technology offer opportunities.

Pest movement/population dynamics and DNA (Priority = High)

Studying pest movement and population dynamics, particularly using DNA tools (e.g. microsatellites), has the potential to allow pest managers to be more prepared and less reactive. Information on a more local level would allow insect models to be linked to farming system models, and to examine refuge options/effectiveness in relation to gene flow.

National initiatives (Priority = Moderate to High)

Coordination of research in all of the above areas will improve the likelihood of long-term data sets being collected (e.g. light traps).

Modelling (Priority = Medium)

Modelling offers opportunities to reduce the amount of survey data collection, once models are validated. Modelling is constrained by the availability of long-term data sets and the perception that modelling is too costly. Web based models made available by various individuals/organisations tend to be available only spasmodically.

Insecticides and Transgenics

Balanced approach (Priority = High)

There is a perceived complacency in the industry (cotton) in relation to what transgenic crops will mean in terms of pest management. The group identified a need for an integrated approach to the deployment of transgenic crops which ensures the maintenance of knowledge and skills in managing pests in non-transgenic crops.

Resistance management (Priority = High)

Ongoing monitoring of resistance trends is important, including the development and deployment of rapid monitoring techniques. There are opportunities to integrate a wider range of options, as they become available e.g. new genes, insecticides (particularly those with new modes of action), within crop management. There was concern about the implications that the widespread introduction of transgenic cotton will have for the progressing of new insecticides, Uncertainty about the practicalities of managing resistance if it is detected.

Wider opportunities for transgenics (Priority = Medium)

There are opportunities to develop transgenic crops to control sucking pests, in cotton, and helioverpa in other crops, particularly the pulses. It was recognised that there are currently challenges with consumer acceptance of GM food crops. There are concerns about the cost of the technology for growers, and getting an appropriate expression of the control mechanism for Australian species and season.

New chemistries (Priority = Medium)

To ensure the maximum benefit and longevity of new products, there must be an investment of time for extension to educate growers in their use. New products are increasingly costly, and are not available for all industries; cotton is generally the primary market – this is an issue for pulses and other grains.

Health and Environment Benefits (Priority = Medium)

Pesticide reduction can be achieved through the integration of natural enemies, transgenics, more strategic use of pesticides and “Attract and Kill” technology. The benefits will accrue to the farm worker, environment and the industries.

Biopesticides

Addressing grower perception of performance (Priority = High)

Grower confidence in NPV is influenced by the perception they have of the performance of the product. The perceptions growers hold of NPV is highly variable based on experience in different crops, at different pest pressure and speed of kill. In some instances, grower enthusiasm for NPV exceeds the real potential of the product. Grower education is essential to ensure confidence in NPV is maintained and built on.

Make them work! (Priority = High)

To ensure that biopesticides are used as effectively as possible, R&D needs to continue to develop and refine techniques for maximising their efficacy in the field. For example, the investigation of

additives, the dose and frequency of application, and timing of application. Genetic manipulation of biopesticides may improve performance.

Biopesticides as tools for IPM (Priority = Medium)

Biopesticides are widely considered to be 'soft' options for a range of pests. In particular they offer options for sucking pests, which are notoriously difficult to control without using chemicals that disrupt an IPM program.

Commercialisation (Priority = Medium)

There are a number of challenges associated with commercialising biopesticides including

- Quantifying the commercial potential
- Cost of production
- Uncertainty about the regulatory processes
- Competition with multinationals
- Appropriate storage of biopesticides on farm.

New Areas (Priority = Medium to Low)

There are opportunities for the application of biopesticides to industries other than broad acre grains and cotton, particularly in horticulture. However, there are a number of constraints to the direct transfer of current knowledge of biopesticides, such as differing pest thresholds, and biopesticide-crop interactions.

Public acceptance of biopesticides (Priority = Low)

Semiochemicals

Evaluating a new tool – potential applications (Priority = High)

Semiochemicals represent a new option in pest management that is not a pesticide. Potentially, semiochemicals offer an option that will reduce the need for insecticide, or replace some insecticide applications. The cost:benefit analysis of semiochemicals needs to be done in this context, because the products themselves are potentially costly in comparison with conventional insecticide options. There may be some off-target impacts of the semiochemicals in an 'attract and kill' mode, these impacts need to be evaluated.

The application of semiochemicals to current and evolving IPM programs needs to be investigated. They are potentially tools for the area-wide management of *helicoverpa* and resistance management in conjunction with transgenic crops. In these contexts, information on the movement of moths and the forecasting of local emergence will be essential.

Regulation (Priority = High to Medium)

Regulatory authorities are unfamiliar with the use of semiochemicals, and currently the registration of such products face the same process that applied to insecticides, which may not be appropriate.

Developing semiochemicals (Priority = Medium)

Semiochemical research is exploratory (difficult) in the early stages, and requires a commitment to funding to reach a commercial conclusion, as quick results are unlikely. However, there are opportunities for national and international collaborations both in research and commercial development of these products.

Education in the application of semiochemicals (Priority = Medium)

Semiochemicals need to be promoted in 'partnership' with other options. Effectiveness is difficult to measure, and growers are unlikely to see immediate results in the same way they have with insecticides, particularly if semiochemicals are used in an area-wide context. Education will be important to avoid the perception that the product is not working because there are no dead moths visible.

DNA Applications

Understanding what DNA-based tools can deliver

Scientists and growers are largely unaware of the potential application of DNA techniques to their work. There is a need to increase the general level of awareness of the opportunities, and the potential benefits of using these tools.

Areas in which DNA has application are:

Ecological studies

- Tools to understand predator/prey ecology
- Tools to support movement studies and ecology
- Get a handle on communities and ecology
- Monitor resistance gene frequency changes under AWM
- Will give basis for new targets for chemicals – protein structures and target genes and GM targets
- RNAi

Service delivery

Providing researchers and industry with tools. There are a number of opportunities to provide DNA services through private/public partnerships, quality assured services and databases.

DNA-based resistance monitoring mechanisms

Opportunities exist to apply DNA techniques to support pest population and resistance monitoring. For example, in Bt resistance, DNA techniques offer opportunities to understand mechanisms of resistance/pest biology and to speed up the monitoring process by testing for multiple products in a single test.

Costs and funding

- Long population data sets are expensive to compile, both in terms of the technology and the time needed to process samples.

Appendix A. Workshop Participants

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APPENDIX B. Voting Form and Instructions

1. You have a total of ten (10) votes to allocate. Place a number in each box to nominate the number of votes you give to each listed topic. You may allocate more than one vote to an individual topic to reflect its relative importance.
2. Tick the box that indicates the industry group you are aligned with.
3. Tick the box that indicates the region you work in.

| | |
|-----------------------------|------------------------------------|
| <input type="checkbox"/> | Area Wide Management |
| <input type="checkbox"/> | Insecticides and Resistance |
| <input type="checkbox"/> | Biopesticides and Resistance |
| <input type="checkbox"/> | Transgenics and Resistance |
| <input type="checkbox"/> | Natural Enemies |
| <input type="checkbox"/> | Climate, Movement and Forecasting |
| <input type="checkbox"/> | DNA Applications |
| <input type="checkbox"/> | Semiochemicals |
| <input type="checkbox"/> | Novel Options |
| <input type="checkbox"/> | Extension and Area Wide Management |
| <input type="checkbox"/> | Evaluation |
| <input type="checkbox"/> | |
| Do you work mainly with : | |
| <input type="checkbox"/> | Cotton |
| <input type="checkbox"/> | Grains |
| <input type="checkbox"/> | Horticulture |
| What region do you work in? | |
| <input type="checkbox"/> | NE Aust |
| <input type="checkbox"/> | Southern Aust |
| <input type="checkbox"/> | SW Aust |
| <input type="checkbox"/> | NW Aust |

Appendix C. Identifying Key Issues

Small groups worked on the selected topics using a pinboarding exercise. Participants considered the opportunities and constraints to improving helioverpa management. They were encouraged to think broadly, and even include ideas which were unrealistic at the moment. The constraints listed contained any 'unmentionable' problems, as well as current and foreseen constraints.

The question for this exercise was:

“What are the opportunities and constraints for this topic to improve helioverpa management nationally?”

The full results of each of the pinboarding sessions are included below.

Session 1

1. Insecticides and Transgenics

1.1 Silver bullet mentality; Reduced conventional options; Balanced approach

Constraints

- Lack of good information on value of refuges to transgenic situation
- Reduced incentive to develop new conventional options
- Bollgard®II high adoption will be a constraint against development of new insecticides
- Need money value for resistance
- 90-95% Bollgard®II across big areas must be predisposing to development of resistance
- Transgenics could lead to 100% loss of existing options
- Must be used as integrated system, and not seen as a silver bullet
- Complacency and silver bullet approach
- Why allow full Bollgard®II and potentially allow skills of managing conventional be lost to the industry?

1.2 Wider opportunities for transgenics; Transgenic cotton – sucking pests; Transgenic pulses

Opportunities

- Transgenic (Bt) cottons targeting sucking pests
- Transgenic (Bt) chickpea lines – the Indians are doing it!
- Development of transgenic pulses
- Increase Cry IAc expression further into growing season

Constraints

- Acceptance of transgenic technologies in food crops
- Transgenic value constrained by inappropriate expression
- Inappropriate expression of Cry IAc because Bollgard®II not truly stacked
- Transgenic technology driven by USA industry and species that are more sensitive to Cry toxins

1.3 Resistance management

Opportunities

- Rapid resistance monitoring techniques
- Maybe its time to do away with 'windows' as a basis for insecticide resistance management
- More effective IPM
- New insecticides, new genes
- New models of action

- New selective insecticides with new/varied modes of action
- Proactive resistance management
- Maintain options
- Potential exists to better manage conventional cotton within framework of Bollgard®II, e.g. 2/3 – 1/3 conventional embedded.

Constraints

- Should a mandatory insecticide late season for Bollgard®II for heliothis be considered?
- Resistance is long term work and adequate funding can be a problem
- More monitoring required
- Resistance frequency
- What is going to happen with Bollgard®II if field resistance is picked up
- When it comes to resistance management science gets rolled by commercial interests every time!
- Lack of 100% compliance to IRMS and means to accurately determine compliance

1.4 Pest monitoring is key component

Opportunities

- Bollgard®II offers good basis for softer, well planned and monitored control of secondary pests of cotton
- Better understanding of source of secondary pests is key to IPM in Bollgard®II

1.5 New insecticides require greater monitoring – improving IPM awareness

Constraints

- New chemistry requires more information for growers to avoid inappropriate use
- All commodities may not have access to all chemistry
- Lack of new products and flow on from cotton to associated cropping
- Higher costs of new chemistry

1.6 Health and environmental benefits; Good for environment; Good for human health; Good for beneficials; Transgenics decrease pesticides

Opportunities

- Greater role of many aspects of IPM in conjunction with insecticides
- Pesticide reduction
- Decrease insecticide use with transgenics
- Positive health benefits on-farm for workers and owners
- Promotion of beneficials with less chemical use
- GMOs improve environmental outcomes of our industries
- Targeted pesticide use for pulses “Attract and kill”

Constraints

- Unavailability of effective “trap and kill” technology for broadacre pulses

2. Natural Enemies

2.1 Natural populations encouraging

Opportunities

- Enforcement of pests – e.g. SLWF will boost need for beneficials
- 24 hour workforce at no extra cost
- Natural enemies are sustainable
- Conservation and enhancement
- Community desire for green control options
- Can contribute to a low intervention system
- Natural enemies control pests
- Most natural enemies are free

2.2 Area wide management

Opportunities

- Habitat for natural enemies
- AWM of natural enemies – building landscapes
- Farming system for natural enemies in dry times
- GM/Bt cotton opportunity to use as refuge for *Trichogramma* etc.
- Opportunities with AWM to increase understanding and utilization of natural enemies
- Ecosystem services considered during revegetation practices
- Manipulating farm landscapes to maximise impact
- Generalists conservation

Constraints

- Thinking beyond the square
- Climatic conditions can make establishment of natural enemies difficult
- Variability and inconsistency
- Changes in beneficials year to year etc, no scope for recipe recommendations
- Poor understanding of movement capacities
- Insufficient information to predict benefits for a given population
- Unable to quantify mortality by predation

2.3 Molecular applications – e.g. diagnostic tools

Opportunities

- Elisa techniques for evaluation of predators
- Molecular identity of prey to improve understanding of role of individual predatory species
- DNA 'Diagnostics' for natural enemies deployed
 - Who is eating whom?
 - % parasitism and by what?
 - % diseased and by what?

2.4 Commercial production releases

Opportunities

- Area wide releases of *Trichogramma*
- Mass rearing of predators and parasitoids
- Mass production of egg and larval parasitoids using artificial diet – (long term - particularly horticulture)

Constraints

- Cost of production is high
- Commercial availability of natural enemies in some areas is limited

2.5 Knowledge of natural enemies; Basic biology

Opportunities

- Need better understanding of predators impact in crops
- Australian native insects plentiful – research opportunities to discover new natural enemies
- Better understanding of what is out there
- Need to choose 'focal' species
- Targeted specialists i.e. *Trichogramma* and other parasitoids
- Managing endemic *Trichogramma* through season (conservation biocontrol)

Constraints

- Knowledge about prey choice and quantity consumed
- Knowledge about environment-crop-natural enemies-pests interaction
- Lack of knowledge about natural enemies
- Natural enemies are poorly understood
- Difficulty in assessing beneficial populations – especially parasites
- Difficulties in sampling all guilds of predators efficiently
- Poor understanding of basic ecology of many natural enemies
- Complexities of large numbers of species
- Poor understanding of important natural enemies (relative impacts)

- Poor understanding of spatial and temporal dynamics of natural enemies
- Not understanding the specific environment for build up of natural enemies
- Program movement of natural enemies
- Poor understanding of new chemistry impact on specific beneficial groups

2.6 Novel helpers

Opportunities

- Use of moth attractants will give pre-emptive strike and lower caterpillar populations for beneficials
- Use Magnet to help manipulate/promote refuges for natural enemies
- Transgenic impacts on natural enemies

2.7 Pesticides and natural enemies

Opportunities

- Development of pesticide resistant beneficials
- Some new soft insecticides in the pipeline
- Better understanding of the effects on newer selective insecticides on natural enemies
- Greater use of soft options will boost beneficials
 - The loop effect
- Widening the registration of selective chemicals

Constraints

- Effect of insecticides on beneficial insects
- Susceptibility to pesticides
- New selective insecticides are more expensive
- Not enough known of adverse (sub-lethal) effects of new chemistry on natural enemies

2.8 Extension industry participation

Opportunities

- AWM may be means for monitoring workshops
- Industry's high priority for extension efforts to increase grower/consultant knowledge of natural enemies
- Wider appreciation of the effectiveness of *T. pretiosum*
- Growing acceptance and use of natural enemies e.g. *Trichogramma*
- Horticulture adopting what has been done in broadacre agriculture

Constraints

- Educating growers of importance of beneficial insects
- Drought issues may dominate growers minds
- Difficulty in getting AWM off the ground
- Publication
- Short life cycle crops
 - e.g. baby leafy vegetables – difficult to get natural enemies established and working for short crop

2.9 Economics of beneficials

Opportunities

- To understand the value of natural enemy activity in the field

Constraints

- Cost benefit analysis for adoption
- Putting a value on natural enemies

2.10 Research funding

Constraints

- Limited funds for national surveys of natural enemies
- Where do the research monies come from?
- Triple Bottom Line (TBL)
- Predictions

2.11 Better employment paradigms

Opportunities

- Let's form a natural enemy working group!!

Constraints

- Funding long-term – beyond PhD
- 'Fractionated' research groups

2.12 Quarantine issues - classical biological control introductions

Constraints

- Need to avoid cane toad experience, but access to exotic natural enemies is very slow. AQIS red tape

3. DNA Applications

3.1 Resistance monitoring & mechanisms

Opportunities

- Understand the gene level mechanisms of resistance/pest biology
- Bt resistance monitoring – same advantages as insecticide resistance monitoring
- Resistance monitoring
 - Fewer insects
 - Multiple resistance from individual insects

3.2 Service delivery availability and cost

Opportunities

- Establish NATA/LQMS service delivery for DNA technology
- Get the DNA tools out of the lab and into accessible service
- Establish DNA taxonomic tool database that is maintained and accessible
- Molecular techniques can operate across industries
- A commercial and public partnership to deliver DNA services

Constraints

- Data availability
- Genome sequencing
- Costs and willingness to pay for diagnostics and DNA tools
- Lack of NATA quality assured services for DNA/diagnostics tools
- Funding for private/public DNA services
- Lots of complex data

3.3 Ecology

Opportunities

- Molecular band diagnostics could help revolutionise IPM and AWM knowledge
- Movement and why?
- Use DNA tools to understand predator ecology
- Opportunity for ecologists and molecular biologists to work together – educating both!!
- Use DNA to get handle on community and ecology
- Understand genomics of insect pathogen variability and evolution
- Powerful tools that can provide answers to questions that are difficult to address by other means
- Will give basis for
 - Population structure
 - Resistance mechanisms
 - New targets
 - Crop breeding/preference

3.4 Research cost and funding

Constraints

- Funding for long population data sets
- Costs
- Time
- Money

3.5 Understanding

Constraints

- Lack of understanding of the technology by most scientists etc.
- Community awareness
- Need to clearly identify opportunities and how they will help industry

3.6 Information

Constraints

- Information of genetics of resistance in *H. armigera*
- Fear that the biotech guys will want to take our information

4. Semiochemicals

4.1 Is a new option, not a new pesticide in pest management; Perceived usefulness (effectiveness)

Constraints

- Measuring effectiveness
- Farmers attitude that if they don't see dead moths, the technology doesn't work
- Difficult for growers to see immediate benefits (due to area wide impacts)
- Needs to be a 'partnership' with other options

4.2 Some insecticides are cheaper; Perceived cost/benefit ratio?; Cost

Constraints

- Potentially expensive
- Cost
- Cost in comparison with current methods

4.3 Difficult science; The difficulty is in finding the chemical – the remaining processes are much easier

Constraints

- Funding and people to develop semiochemicals to commercial stage.
- Getting and funding co-operation on area basis for using semiochemicals to reduce overall population
- Quick results unlikely
- Difficult science

4.4 Government authorities may complicate and/or delay widespread adoption; Regulation

Constraints

- Obtaining registration on wide variety of vegetable crops (same as for insecticides)
- Regulatory authorities not used to semiochemical approaches

4.5 May be unforeseen effects (as with insecticides); Environmental

Constraints

- Potential effects on non-target organisms

4.6 Has a number of uses and applications in pest management; Potential uses and applications in pest management

Opportunities

- A tool for Area Wide Management
- Chances to use semiochemicals to reduce overall populations in district (particularly isolated, smaller areas)
- Has area wide impacts on helioverpa oviposition (i.e. not only on treated field)
- Resistance management as part of Bollgard®II for CQ
- Interaction with transgenics
 - Manipulation of refuges, 'moth busting'

Constraints

- Weather – effect of rain
- Forecasting emergence of moths

4.7 New option in pest management (not a new pesticide); New tool

Opportunities

- Additional 'soft option'
- Novel tool for IPM
 - Less insecticide use
- New option for pest management
- Use semiochemicals to replace some use of broad spectrum insecticides
- Benefit in clean green concept and promotions
- 'Partnership' with other options in pest management

Constraints

- Integration with current methods

4.8 Opportunities for Australian business to lead a new area; 'New Science'

Opportunities

- Fosters collaboration
- International significance

5. Evaluation

5.1 Justify adoption

Opportunities

- A way to demonstrate impact of project activities – empirical?
- Provide cost benefits
- Skills for identifying what needs to be evaluated - transfer more research to the paddock
- Promote society expectations
- Information days on IPM
 - Level of interest
- Use evaluation data to provide the dollar outcomes to growers
- Different levels of extension e.g. trial program

Constraints

- Social issues need addressing by experts
- Evaluate what? Impact of ? ? ?
- AWM not economically (\$) justified; retards participation
- Political correctness
 - Duty of care
- Always trying to justify success – need to challenge ourselves
- Ease of spraying verses IPM/AWM
- Widespread belief in results
- Expanding year in year out variation so no one can derail mission

- Wary of results unless done on own farm
- Lack of embedded economists
- Lack of experimental 'control' areas
- Cheap price of pyrethroid

5.2 Inadequate economic data

Opportunities

- Use historical population data to compare dollar outcomes with IPM practice
- Provide direction on 'how' to adopt sustainable helioverpa management
- Increase the knowledge level of what is achievable
- Prove industry stewardship to the city/eastern sea board
- Use DNA technologies to monitor populations under IPM strategies e.g. push/pull
- Planning tool, reporting tool
- Economic evaluation
- Resources for gathering information e.g. Networks, AWM groups
- Use historical population data to compare insecticide sales by season
- Information required for government and funders to justify expenditure
- Tailor decision support tools to better support AWM and benchmarking
- Enhance existing modelling tools to 'evaluate' scenarios
- Why haven't we evaluated?
- Farm based profitability analyses verses helioverpa population data verses control strategy
- Leverage the high level of compliance to IRMS and AWM to establish a national data bank
- Imperative for understanding and improving project activities/outcomes
- Huge amount of data available for analysis
- Surveys of the industry
 - Why do farmers/consultants etc. make their decisions to use/not use IPM?
 - How much risk do they see associated with IPM as compared to conventional? Why?

Constraints

- Lack of 'control' areas for comparison – opportunity for modelling
- Collecting enough commercial farm information
- Extension resources (research the common priority)

5.3 How to evaluate; Benchmarking

Opportunities

- Pre-crisis benchmarking
- Modelling to allow evaluation/impacts on populations of pest
- Building on approaches and experiences in different industries
- Link research and development with extension activities and practice change

Constraints

- Amount and quality of data by time to get a meaningful result
- Entomologists generally are not trained in evaluation of non-technical aspects
- Better/improved skills in triple bottom line (TBL) reporting on project basis
- Hardly anyone (including R&D knows what or how to evaluate)
- True comparison on-farm of the R&D is traditional
- Privacy perception - quality of survey to industry
- Need for 'good' published studies in evaluating change economic/attitude/social/environment

5.4 Why evaluate?

Constraints

- Lack of social research collaboration
- Shortage of people capable, and with time to address issue
- Resources prioritised to have research transfer to the paddock
- Who's going to do it and with whose money?

5.5 Skills and resources we need...

Opportunities

- Greater group involvement by farmers and agronomists
- Information packaging with greater extension involvement
- AWM/IPM groups provide opportunities for benchmarking and ongoing evaluation
- Use AWM groups to push IRMS further along IPM continuum

5.6 Skills

Opportunities

- Need to enlist social sciences to understand why success/failure

SESSION 2

6. Biopesticides

6.1 Public acceptance

Opportunities

- Warm and fuzzy
- Environmentally friendly (acceptable)
- Consumer acceptable
- Community desire for soft options
- Plenty out there (unchartered territory)

Constraints

- Non target impacts and 'flaring'
- Benefits over synthetics debatable (plant extracts)

6.2 "New Areas"

Opportunities

- Horticulture

Constraints

- Tomatoes - thresholds, plant itself

6.3 Commercialisation

Constraints

- Funding for development
- Quantifying commercial opportunity
- Cost
- Benefit to cost of biopesticides
- Technical difficulties
 - Scaleup
 - Stability
 - Plant chemistry
- Cost (but fungi will be cheaper)
- Uncertain regulatory process
- Difficulty in competing in market containing multi national companies
- Storage problems on farm

6.4 IPM fit

Opportunities

- Crack the suckers (maintain IPM)
- High specificity
- IPM compatible
- Soft option compatible with other IPM tactics
- Soft option

- Multipest constraints - SLW and need for soft options
- Biopesticides effect on natural enemies
- Useful for specific times, situations
- Selective
- “Resistance” slow to develop
- Fit for biopesticides in IPM and thresholds for biopesticides
- Population management

6.5 Perception of performance

Constraints

- Effectiveness
- Sheltered feeding sites
- Inconsistency of efficacy of biopesticides at high helioverpa pressure
- Slow killing effect of biopesticides in the field
- Slow acting
- Multi pest scenarios
- Enthusiasm exceeds performance
- Not effective enough in some crops (high value, low threshold)
- Grower confidence - that they work and have benefits
- Need grower education

6.6 Make them work

Opportunities

- Rate, time of application to increase efficacy
- Repeat low dose application of NPV
- Improve application
 - ULV/aerial
 - Fan/air assisted
- Use NPV with effective additives – molasses, PSOs?
- Extension
- Potential for genetic manipulation to improve performance
- Need to ‘tweak’ soft options for maximum effectiveness

7. Climate, Movement and Forecasting

7.1 Data

Opportunities

- Lack of long term data on abundance on which forecasting is based
- Linking historical time-series analysis with chemical use and crop area data
- Broad range, long time scale monitoring using sufficient molecular data

Constraints

- Long term data available?
- Need for long term projects – funding
- Funding to support infrastructure
- Funding
 - Costs of meteorology data for web-based models
- Access to commercial farm data
- Constraints for DNA work seems to be costly

7.2 Pest movement, population dynamics and DNA

Opportunities

- Linking spatial insect models with farming system models
- Will allow us to be more prepared, more alert
 - More aware
 - Less reactive

- Opportunities to tie movement data and genetic information to examine gene flow (refuge effectiveness)

Constraints

- Local movements, e.g. efficiency of refuges and linkage to transgenic cotton
- Testing value of refuges for transgenic resistance management strategy along with information on gene flow
- Opportunities to tie movement data and genetic information to examine gene flow (refuge/resistance management strategy effectiveness)
- Southern (cooler) cotton districts
 - Poorer understanding of population dynamics
- Studies have only confirmed what most believed. Reasons for movements not yet explained
- Translating “area wide data” to local!!!
- Insecticide resistance management

7.3 Modelling

Opportunities

- More technology and model based – less survey type data collecting

Constraints

- Long term monitoring of population abundance
 - Climatic drivers
- Constraint for DNA studies – current lack of understanding of this technology
- Inadequate cost – benefit analyses (= perception of high cost)
- How to incorporate forecasts into AWM?
- Accuracy

7.4 National Initiatives

Opportunities

- Opportunity for pest management in the climate resource
- Co-ordination of molecular efforts to service arthropod studies
- National co-ordinated effort for DNA studies to focus on movement

Constraints

- Lack of long term data sets
 - Light traps, pest abundance

7.5 Forecast

Opportunities

- Regional and local forecasting (automated)
 - Delivery to desk like weather forecast
- Other predictors for medium to long term forecasts
- Long range SOI-based forecasts for *H. punctigera*
- New insights from DNA work in *H. armigera*
 - What drives long range movement?
- Opportunity for entomology and climatology to join forces
- Generating a “null” climate model for evaluating AWM etc.
- Helicoverpa “weather” forecast on the ABC!
- More accurate pesticide forecasting
 - Less stockouts
- Gentime model for web
 - Linked to PPD
- Dispersal model back on web
 - Useful for many pests (particularly incursions)
- Tools for interpretation of population structure
- Gentime model generalised for range of species
- Diapause model to be web-based
- Accessible tool box of simple forecasting tools

Constraints

- Pre-emptive management via forecasting

- Accuracy?
 - Are they accurate?
- Level of 'skill' in rainfall and temperature forecasts
- Short term forecasts of migration hard
 - Which way will the wind blow?
- Need for validating in range of areas

8. Extension

8.1 Co-ordinating integrated service delivery

Opportunities

- Integrate and co-operate in service delivery (teams)
- There is a large but fragmented extension provider capacity
- Network exposure

Constraints

- Insufficient extension co-ordinators
- Experience to counteract client negativity
- Extension provider fragmented _____ a range of government/private identities
- Potential resourcing base to ensure team

8.2 Resources for maintaining extension

Opportunities

- Networks
- User pays

Constraints

- Reduced helioverpa funding to maintain quality extension
- Loss of knowledge (disappearing research)

8.3 Identify opportunity for extension (key drivers)

Opportunities

- Identifying areas for opportunities to change/support helioverpa management

Constraints

- Lack of economic awareness of data
- "Want to" change (i.e. aspirations)
- What are we trying to change or impact on?

8.4 New approaches

Opportunities

- New models for extension
- Pro-active approach

Constraints

- Trap of being bound in thought pattern by the industry
- New ideas for knowledge management

8.5 Packaging and re-packaging

Opportunities

- Being responsive to the context of extension (pre-crisis ↔ crisis ↔ post-crisis)
- Converting all this R&D into user friendly extension packages
- Information 'overload'
- Farmers want to adopt more sustainable systems
- Inter-relations with clients
- Capitalise on proven course & training programs - ensure relevant

Constraints

- Need to talk the same language

- Information not packaged in a user friendly form
- Research not evaluated

9. Area Wide Management

9.1 Linkages

Opportunities

- Foster consultants collaborating at a regional level
- Linkage across industries
- Opportunity to develop cross commodity approach
- Horticulture incorporation

Constraints

- Large range of commodities e.g. horticulture
- Need to improve links between cotton, grains and horticulture on joint pests

9.2 Benefits

Opportunities

- Reduced pests and pesticide use
- Integrate IRM and IPM strategies
- Facilitates resistance management programs
- Opportunity for removal of strict constraints of IRMS
- Opportunity for resistance management area wide to remove mosaic effect
- Capitalise on ecosystem services
- Better able to manage high pest pressure periods
- Increase communication between industry, research and extension
- AWM groups serve as vectors for crisis management
- Potential for AWM for natural ecosystem services also
- Synergies between crops and habitat
- Networks
 - Better able to respond to crisis in region/industry

9.3 Extending outside the square breadth

Opportunities

- AWM offers opportunities to control helicoverpa and other pests in one program
- AWM to extend beyond pests
- Manage the system
 - Manage the pests
- Collaboration on how to manage AWM groups
- AWM facilitates education on IPM and natural enemies
- Capturing the group
 - \$
 - Social
 - Research
- Non crop incorporation

Constraints

- Grower participation
- Other pest outbreaks e.g. SLWF

9.4 Extension

Opportunities

- Good news stories – a regular feature
- The times is right to build on success
- Attitudes are changing – capitalise on this

Constraints

- Convincing argument for change

- Complacency – all is well, no need to change
- Need local drivers for successful AWM
- Generation of new topics for discussion
- Other major issues like water, drought

9.5 Drivers

Opportunities

- Provides a basic framework for dealing with a range of district issues
- Industry development officers and extension officers assist with co-ordinating growers and local communities
- Knowledge base is great – get information out

Constraints

- Lack of enthusiasm in growers and communities to use AWM
- Perceived need as no immediate crisis
- DPI&F decreasing extension officer numbers – need more
- Funding constraints e.g. linkages with horticulture
- Time and energy of staff to drive process
- Need government extension personnel to support AWM
- How can we quantify the impact of AWM?
- Maintaining interest after success
- Maturing of group over years
- Obtaining information for evaluation
- If AWM decisions are wrong then major problems across entire areas; then need for good understanding, knowledge and extension
- Economic justification for change
- No current crisis to stimulate action and adoption

9.6 Attitudes/culture

Constraints

- Conflicts of priorities between commodities
- Culture of individualism within industry (especially vegetables)
- How big is the 'area' of AWM?
- Historical lack of co-operation among growers
- Non compliance due to different individual grower/farm restraints

9.7 Risk of complacency

Constraints

- Distances to travel

Appendix D. List of abbreviations used in this report

AGM: Annual General Meeting
APSIM: Agricultural Productions Systems Simulator
APVMA: Agricultural Pesticides and Veterinary Medicines Authority
AQIS: Australian Quarantine Inspection Service
AWM: Area Wide Management
BDI: Beneficial Disruption Index
BGI: Bollgard®II
BMP: Best Management Practices
Bt: Natural toxin from bacterium *Bacillus thuringiensis*
CCA: Cotton Consultants Australia Inc.
CGS: Cotton Grower Services
CQ: Central Queensland
CRDC: Cotton Research and Development Corporation
CRC: Cooperative Research Centre
CSIRO: Commonwealth Scientific and Industrial Research Organisation
DBM: Diamond Back Moth, *Plutella xylostella*
DNA: Deoxyribonucleic Acid
DPI: Department of Primary Industries
DPI&F: Department of Primary Industries and Fisheries
EMS: Environmental Management Systems
GIS: Geographic Information Systems
GM: Genetically Modified
GMO: Genetically Modified Organism
GRDC: Grains Research and Development Corporation
GVB: Green Vegetable Bug, *Nezara viridula*
HAL: Horticulture Australia Limited
HEAPS: HEliothis Armigera and Punctigera Simulation
IDO: Industry Development Officer
IGR: Insect Growth Regulator
IPM: Integrated Pest Management
IRMS: Insecticide Resistance Management Strategy
LQMS: Laboratory Quality Management System
NATA: National Association of Testing Authorities
NPV: Nucleopolyhedrovirus
NSW Ag: New South Wales Agriculture (now Department of Primary Industries)
PSO: Petroleum Spray Oils
QA: Quality Assurance
R&D: Research and Development
R,D&E: Research, Development and Extension
RNAi: ribonucleic acid interference
SARDI: South Australian Research and Development Institute
SLWF: Silver Leaf Whitefly, *Bemisia tabaci*
TBL: Triple Bottom Line
UNE: University of New England
UQ: University of Queensland
UV: Ultra Violet