

# Program Two

## *Innovative Technologies*



Dr Stephen Allen and Associate Professor Peter Gregg - Program 2 Leaders.

### INTRODUCTION

Commercial cotton production relies on a number of chemical inputs for high levels of production. While progress has been made in adoption of transgenic plants, Integrated Pest Management (IPM) and Best Management Practice (BMP), there remains an imperative to seek alternative management tools which minimise dependence on disruptive pesticides. This program reflects the need for innovative solutions to pest, weed and disease problems and the need for new tools to remediate or monitor environmental impacts. The program also includes fundamental work on the molecular genetics of cotton, which will aid in breeding for various characteristics including pest and disease resistance and fibre quality

There have been seven Cotton CRC funded projects and 17 CRDC projects addressing the aims and objectives of the 'Innovative Technologies' program. Seven postgraduate students are associated with these projects (See below).

### AIMS AND OBJECTIVES

To research and develop innovative technologies which provide an improved range of options for environmentally acceptable crop management and bioremediation.

- To rigorously evaluate the efficacy and environmental impacts of new transgenic plants.
- To develop and evaluate the use of attractants and repellents for *Helicoverpa* spp.
- To identify and evaluate effective biocontrol agents for soil-borne pathogens of cotton.
- To investigate the use of 'biofumigation' and 'systemic induced resistance' for improving the efficacy of disease control strategies.
- To develop more effective and user-friendly diagnostic kits for rapid detection of pests and diseases in plant tissues and in soil, and for pesticide residues and pest resistance.
- To investigate bioremediation techniques for pesticide contamination on cotton farms.

The utilisation of new technologies emerging from this program will be developed in Program 3, in the context of sustainable farming systems.

### HIGHLIGHTS AND ACHIEVEMENTS

*\*Evaluation and Management of Transgenic Cotton.*

The previous seasons experiments were repeated and results again demonstrated the high and consistent efficacy of Cry IAc/Cry 2Ab combinations and of Cry 2Ab alone. The presence or absence of the Roundup Ready gene had no impact on efficacy. There was no clear evidence that waterlogging had an influence on the Bt protein. Further work is needed on the impact of plant damage on efficacy and Bt protein concentration.

\* *Semiochemical Approaches to Control Helicoverpa spp.*  
For the first time, attract-and-kill formulations containing plant volatiles and insecticides were tested in open field conditions, on corn and beans in the Bowen district. Large numbers of *Helicoverpa armigera* moths were killed, in relation to the relatively low population density, and the unexpectedly long persistence of the formulations was very encouraging. A full patent application has been submitted, including Patent Cooperation Treaty applications for overseas countries. Negotiations with potential commercial partners are proceeding.

\* *Managing Helicoverpa spp. on cotton with Semio-(signalling)-chemicals*  
This project commenced only this year. Two Professional Officers have been appointed, one (Dr. Ho Dang) at ACRI and the other, Ertong Wang, at QDPI. Preliminary studies have identified oviposition preferences for *Helicoverpa* spp. on cotton and a number of other crops have been established. A plant which has oviposition deterrent and direct toxic effects has been identified, and analysis of its chemical composition using HPLC techniques is in progress.

\* *Pheromones for occasional pests of cotton.*  
This project began in January 2002. It is conducted by a PhD student, Samuel Lowor, and aims to identify the pheromones of a number of occasional pests of cotton, including common cutworms and rough bollworms, to provide methods for monitoring these pests. Cultures of these pests have been established in the laboratory, and preliminary analyses of the pheromone components of cutworms have been conducted using GC-MS techniques.

\* *Crop management protocols for the on-farm production and utilisation of viral insecticides in cotton*  
Two experimental sites were established in pigeonpea-cotton intercrops. At each site, larval numbers were assessed and a commercial formulation of NPV applied by ground application to the pigeonpea component only at the recommended field rate ('Gemstar' at Lowana and 'Vivus' at the ACRI). Soil, foliage, and ground/canopy insects were recovered before and after application for laboratory analysis to quantify NPV production and movement.

\* *Molecular Diagnosis of Fusarium Wilt of Cotton.*  
A protocol has been developed that allows efficient and sensitive PCR amplification of pathogen DNA from plant material, water and seed. Several soil DNA extraction methods are being compared and evaluated in conjunction with direct pathogen isolation in order to determine the most suitable protocol for detecting the pathogen in soil.

\* *Bioremediation Enzyme for Endosulfan Sulphate.*  
A bacterium with endosulfan sulfate degrading activities has been identified. Researchers have characterised the enzymes involved in endosulfan sulfate degradation from this organism and have begun initial attempts at cloning the genes involved..

## POST GRADUATE STUDENTS ASSOCIATED WITH CRC PROGRAM 2 PROJECTS.

STUDENT	TOPIC
Lisa Gulino	Molecular diagnosis of Fusarium wilt of cotton
Samuel Lowor	Pheromones for occasional pests of cotton
Erica Crone	Characterisation of a potential new insecticidal transgene
Michael Zuckerman	Protease resistant insecticidal proteins for controlling <i>Helicoverpa</i> species
Andrew Davies	Ecology of the Trichogramma egg parasites in the Ord River irrigation area and their role in cotton IPM
Mark Wade	Biology, ecology and utilisation of the Damsel bug as a predator in cotton
David Britton	Studies of slow-release formulations for semiochemicals in cotton pest management

## ASSOCIATED CRDC FUNDED PROJECTS THAT CONTRIBUTE TO THE PROGRAM 2 OBJECTIVES

CSE 82C	Characterisation of a potential new insecticidal transgene
CSE 84C	Insect pest resistance and the role of induced responses to damage in Australian cottons
CSE 88 C	Protease resistant insecticidal proteins for controlling <i>Helicoverpa</i> species
CSP 102C	Isolation of novel cotton promoters to drive the robust expression of useful genes in transgenic cotton
CSP 113C	Australian native cottons as sources of resistance and new pathotypes of Fusarium wilt
CSP 114C	Discovery of genes involved in the expression of cotton resistance responses to Fusarium wilt by the application of microarray technology
CSP 115C	Targeted expression of genes for the manipulation of systemic acquired resistance responses of cotton for improved tolerance to fungal pathogens
DAN 151C	Conservation and utilisation of beneficial insects and other biological control agents for IPM in cotton II
DAN 153C	Managing black root rot of cotton
DAN 154C	Disease of Cotton (VII)
DAQ 105C	Improved application and formulation of viral biopesticides against <i>Helicoverpa</i>
DAQ 107C	Ecology and development of management strategies for Fusarium wilt of cotton
DAQ 111C	New biopesticides against emerging sucking pests
DAQ 116C	Assessment for the potential of resistance to Gemstar
MU 1C	Transgenic cotton for the control of Fusarium wilt
UQ 26C	Ecology of the Trichogramma egg parasites in the Ord River irrigation area and their role in cotton IPM
UQ 29C	Biology, ecology and utilisation of the Damsel bug as a predator in cotton

## LINKAGES

\* *Evaluation and Management of Transgenic Cotton.*  
Monsanto, CSIRO Plant Breeders (Dr Greg Constable, Mr Peter Reid) Cotton Seed Distributors Ltd., CRC for Weed Management Systems (Prof. Rick Roush), University of Melbourne (Dr David Heckel), Queensland Department of Primary Industries (Dr Richard Sequeira, Dr David Murray).  
\* *Semiochemical Approaches to Control Helicoverpa spp.*  
IPM Technologies Inc, USA, Bioglobal Ltd.

\* *Managing Helicoverpa spp. on cotton with Semio-  
(signalling)-chemicals*  
CSIRO Narrabri (Dr. Greg Constable)

\* *Crop management protocols for the on-farm production  
and utilisation of viral insecticides in cotton*  
CSIRO Narrabri (Martin Dillon)

\* *Molecular Diagnosis of Fusarium Wilt of Cotton In Australia*  
Queensland Department of Primary Industries (Dr Joe Kochman),  
CRC for Tropical Plant Protection (Dr Suzy Bently), Cotton Seed  
Distributors Ltd. (Dr Stephen Allen), SARDI (Dr Kathy Ophel-  
Keller, Dr Alan Mackay), C-Qentec (Felice Driver)

\* *Bioremediation Enzyme for Endosulfan Sulphate*  
Orica Ltd. and HRDC (Dr Irene Horne), University of  
Nebraska (Prof. Anthony Zera)

## Project Summaries

**PROJECT NUMBER:** 2.1.01 AC

**Project Title:** Efficacy and field performance of new transgenic cottons

### STAFF

Dr Gary Fitt, CSIRO Entomology, Narrabri, NSW  
Dr Geoff Baker, CSIRO Entomology, Canberra, ACT  
Ms C.L Mares, CSIRO Entomology, Narrabri, NSW  
Dr R Mahon, CSIRO Entomology, Canberra, ACT  
Ms K. Olsen, CSIRO Entomology, Canberra, ACT.

### AIMS

Transgenic cotton varieties expressing the Cry Bt genes (CryIAC and Cry2Ab) from *Bacillus thuringiensis* offer considerable benefits for the sustainability of pest management systems for the cotton industry.

Our main focus in this project is to provide the detailed understanding of field performance of Bt cottons needed to manage them most effectively from a resistance point of view and gain the greatest benefit for pest management.

As a major part of the work we have sought to characterise the many factors which influence the field efficacy of Bt cotton varieties. INGARD varieties expressing only the CryIAC protein have been used commercially for some 6 seasons now. Most research now focusses on the two gene combinations with the addition of the Cry2Ab gene.

## OUTCOMES

During the 2001/2002 we have continued field research at Narrabri and laboratory based work in controlled environments in Canberra. We conducted field evaluations of five varieties expressing the CryIAC and Cry2Ab genes from *Bacillus thuringiensis* (Sicala V3, Sicot 40, Sicot 289 and Siokra V16). One variety, Sicala V2, was available with only Cry2Ab allowing us to assess the influence of this gene alone, while a wide range of varieties expressing Cry IAC were included.

Results using laboratory bioassay of node 4 leaves confirmed results from last season, showing high and consistent efficacy of CryIAC/Cry2Ab combinations and of Cry2Ab alone. The combination of the Roundup Ready gene with either of the Cry genes had no influence on efficacy.

The two-gene combination showed bioassay survival of 10% or less throughout the growing season. We have shown previously that such efficacy would result in no survival under field conditions. As shown previously, the CryIAC plants showed decreasing efficacy up to about 95 days after sowing. Extremely high efficacy of the two-gene plants occurred in tissues from nodes 2 to 7 from the top of the plant.

The influence of factors such as waterlogging and plant damage on efficacy and Bt protein concentration were also continued. In the case of waterlogging we can find no clear evidence of an influence on Bt protein, while for plant damage the evidence is conflicting as yet and further work is needed.

While our results overall indicate that the consistent high efficacy of two-gene cottons will have even greater impact in reducing reliance on pesticides, they are very significant in showing that most of the performance of 2 gene plants relies on the Cry2Ab protein which appears to be more consistently produced in plants over their growth cycle.

This indicates that ongoing vigilance will be required in resistance management, as we clearly do not have a season-long two-gene strategy that would be optimal for long-term delay of Bt resistance. Nonetheless, the two gene plants have considerably less resistance risk than that relying on one gene (CryIAC).



Greenhouse experiments at ACRI Narrabri.

PROJECT NUMBER: 2.2.01 AC

*Project Title:* Crop management protocols for the on-farm production and optimal use of viral insecticides in cotton

#### STAFF

Dr Andy Richards, CSIRO Entomology, Canberra, ACT.  
Ms Janelle Scown, CSIRO Entomology, Canberra, ACT.

#### AIMS

This project is investigating the feasibility of applying a new technique in insect pest management. The technique is based on the “in-field” production of a naturally occurring insect virus (NPV) in late season *Helicoverpa* trap crops and relies on the strategic application of commercial NPV formulations (e.g. ‘Gemstar’, ‘Vivus’) to seed the large-scale amplification of NPV in infected host larvae. The technique then utilises resident populations of insect predators to disseminate field-generated virus into adjacent cotton crops for improved *Helicoverpa* control.

#### OUTCOMES

This year is the second and final year of this project. Field and laboratory studies in the first year showed that while it was possible to amplify NPV in late season pigeon pea, detailed tests showed that predatory earwig species (originally considered to good candidates for disseminating virus) were quite unsuited to this role.

The majority of other ‘beneficials’ including, for example, ladybeetles, spiders, sucking bugs and lacewings, were considered as being unlikely to possess the necessary attributes of abundance, mobility, and larval feeding behaviour, to spread virus effectively - at least on an individual species basis. The possibility remained, however, that in combination cotton ‘beneficials’ may provide sufficient utility and it was determined that this should be evaluated. To this end, the key objective this year was to determine the extent of virus spread into a cotton crop. Experimental sites were established in pigeonpea-cotton intercropped at ‘Lowana’ (a commercial cotton farm in northern NSW) and on a dedicated experimental plot at the Australian Cotton Research Institute (ACRI).

At each site, larval numbers were assessed and a commercial formulation of NPV applied by ground application to the pigeon pea component only at the recommended field rate (‘Gemstar’ at Lowana and ‘Vivus’ at the ACRI). Soil, foliage, and ground/canopy insects were recovered before and after application for laboratory analysis to quantify NPV production and movement.

A regional scarcity of *Helicoverpa* in northern NSW late season meant that the Lowana experiment was discontinued. The application of ‘Vivus’ at the ACRI site, however, did coincide with a very late season influx of *Helicoverpa* in mid-April. The final samples were recovered from the field in mid May. At the time of writing, the majority of post-spray samples are in the process of being analysed and no conclusions can be drawn at this time other than confirmation that a virus amplification event had occurred within the pigeon pea. The full results and conclusions from this study will be presented in the final report.

PROJECT NUMBER: 2.2.03 AC

*Project Title:* Semiochemical approaches to control of *Helicoverpa* spp

#### STAFF

Dr Alice Del Socorro, UNE, Armidale, NSW  
Associate Professor Peter Gregg, UNE, Armidale, NSW  
Mr Richard Tennant, UNE, Armidale, NSW.  
Mr Dan Alter, UNE, Armidale, NSW.  
Dr Chris Moore, QDPI, Brisbane, QLD.

#### AIMS

To examine the role of attractant chemicals in the control of *Helicoverpa* spp. The project is in its second year, and follows from a project of the previous CRC for Sustainable Cotton Production.

#### OUTCOMES

Our attractants have now reached the stage of commercial development. Our provisional patent application expired in May 2002, and a full patent **application is now in place**. Negotiations with semiochemical companies have been initiated.

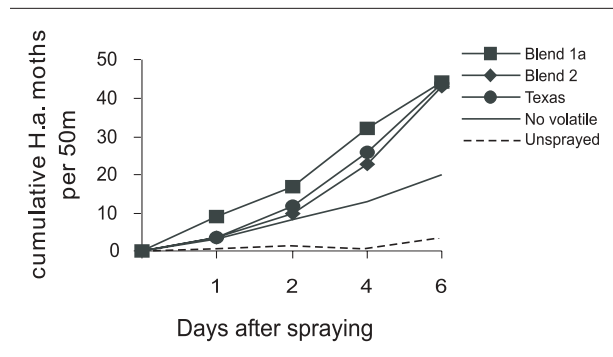
We conducted three open field trials in Bowen, Queensland, two in vegetative sweet corn and one in French beans. In all the trials, we included a previously published attractant blend (Texas blend) for comparison with our own blends, along with a formulation containing no attractant chemicals and an unsprayed section as control. The formulations were based on canola oil with the addition of feeding stimulant, thickener, emulsifying agent and antioxidants. All blends contained insecticide (0.5% methomyl).

During the first sweet corn trial, numbers of *H. armigera* killed ranged between 12 and 14 per 50m of treated row. In the second corn trial, the numbers of *H. armigera* ranged from 42 to 44. In beans, between 24 and 33 *H. armigera* were killed with the attractant treatments per 50 m of row. In all the trials, between 50 and 84% of the *H. armigera* killed were females.

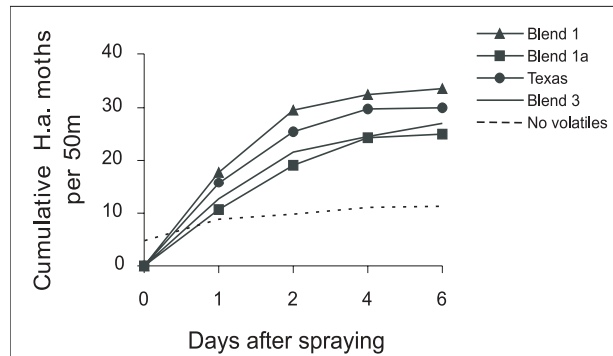
Other than *H. armigera*, other pests killed were *Mythimna convecta* (common armyworm), *M. loreyimima* (sugarcane armyworm), *Spodoptera litura* (cluster caterpillar) and *Chrysodeixis* spp. (false loopers). The effects of the attractant formulations persisted for up to 6 days.

We also continued field wind tunnel studies in the Darling Downs. We had 60-80% mortality when the weather was favourable (warm and moderately windy nights). Higher mortality was obtained with blends consisting of a combination of floral and leaf volatiles, confirming our olfactometer results that blend complexity is important. Methomyl (0.5%) was a better insecticide than carbaryl (1%). Feeding stimulants such as sugar and molasses were important to keep moths in the vicinity of the lures.

## Sweet corn



## French beans



Cumulative mean numbers of dead *H. armigera* moths per 50m sprayed with attract-and-kill formulations in open field trials, Bowen, Qld, April 2002.



Peter Gregg using a battery powered sprayer designed for application of *Helicoverpa* attractant formulations



Alice Del Socorro setting up a field wind tunnel for experiments on *Helicoverpa* attractants.

PROJECT NUMBER: 2.2.04 AC

*Project Title:* Bioremediation enzyme for endosulfan sulfate

### STAFF

Dr John Oakeshott, CSIRO Entomology, Canberra ACT  
Dr Robyn Russell, CSIRO Entomology, Canberra ACT

### OTHER STAFF & COLLABORATORS:

Dr Irene Horne, CSIRO Entomology, Canberra, ACT  
Prof Anthony Zera, University of Nebraska, USA

### AIM

This project is part of a larger project with several stakeholders. The goal is to develop enzymatic bioremediation technologies for the clean-up of problematic pesticide residues in irrigation drainage waters and on horticultural commodities.

Priority pesticides in the overall project include the organophosphate (OP), pyrethroid, carbamate and endosulfan insecticides and the thiocarbamate herbicides.

This particular project is concerned with the isolation and characterisation of enzyme(s) that will degrade endosulfan sulfate, the toxic breakdown product of insecticide, endosulfan.

### OUTCOMES

We have identified a bacterium with endosulfan sulfate degrading activities and have characterised the enzymes involved in endosulfan sulfate degradation from this organism. We are now in the process of cloning the genes involved.

A provisional patent describing the endosulfan and endosulfan sulfate degrading enzyme systems was filed on 7 June 2002, and an oral presentation was made by Dr Irene Horne at the Second Year Review (Stage 1) of the Australian Cotton CRC, Narrabri, July 2001.



Research technician, Ms Kahli Weir, busy at her lab bench at CSIRO Entomology in Canberra. Kahli, with Dr Tara Sutherland, has isolated a bacterial strain that can degrade endosulfan sulfate, the toxic metabolite of the insecticide, endosulfan.



Preparation of the dilute enzyme solution for field trials of an organophosphate degrading enzyme near Narrabri during the summer of 2000/2001. Here Orica employee, Michael Selleck, mixes 8 litres of enzyme concentrate with 172 litres of a buffer solution. The 180 litres of dilute enzyme solution was subsequently used to treat 80,000L of irrigation run-off.

**PROJECT NUMBER:** 2.2.05 AC

*Project Title:* Molecular diagnosis of Fusarium wilt of cotton in Australia

#### STAFF

Dr Suzy Bentley, CRC for Tropical Plant Protection, Indooroopilly, QLD.

Ms Lisa Gulino, PhD Student, Cotton CRC/CRC for Tropical Plant Protection, Indooroopilly, QLD.

Dr Natalie Moore, QDPI, Indooroopilly, QLD.

Dr Joe Kockman, QDPI, Toowoomba

Mr Wayne O'Neill, QDPI, Indooroopilly, QLD.

Miss Julie Pattemore, CRC Tropical Plant Protection, Indooroopilly, QLD.

Dr Stephen Allen, Cotton Seed Distributors, Narrabri, NSW.

#### OTHER STAFF & COLLABORATORS

Linda Swan, QDPI, Toowoomba, QLD.

Anthony Mitchell, QDPI, Toowoomba, QLD.

Kathy Ophel-Keller, South Australian Research and Development Institute, Adelaide, SA.

Alen McKay South Australian Research and Development Institute, Adelaide, SA.

Felice Driver, C-Qentec.

#### AIM

To develop a DNA-based diagnostic system for the detection and identification of the two Australian genotypes of Fov.

Since Fov was first recorded in Australia in 1993, it has been identified in several cotton growing regions of Queensland and New South Wales. Fusarium wilt is easily spread by the movement of contaminated soil attached to farm machinery, and irrigation water. The risk of establishment of Fov in new areas is also very high because the disease is seed transmissible and fungus has the ability to survive in plant debris and soil as chlamydospores for several decades.

Once a farm is infested with fusarium wilt there is no commercially viable way to eliminate the disease from the soil. The most effective way to control fusarium wilt is to select or breed cotton varieties with resistance to the disease. Other options for management rely on limiting the build-up of the disease through agronomic practices, like stubble management and crop rotation regimes.

#### OUTCOMES

The DNA diagnostic test being developed uses the polymerase chain reaction (PCR) to specifically detect DNA from each of the Australian genotypes of Fov in infected plant material, contaminated seed and infested soil. This test will be invaluable to the industry as early detection of fusarium wilt is critical for containment and control of the disease.



Cotton team taken at Cecil Plaine while addressing sampling issues for the diagnostic test, from L to R Julie Pattemore, Lisa Gulino, Suzy Bentley (All CRCTPP) Richard Danial and Felice Driver (C-Qentec) Stephen Allen (CSD) and Joe Kochman (QDPI).



Joe Kochman, Stephen Alen and Lisa Gulino at Cecil Plains soil sampling for the Fov diagnostic test.

**PROJECT NUMBER:** 2.2.06 AC

*Project Title:* Managing *Helicoverpa* spp. On cotton with semio-(signalling)-chemicals

#### STAFF

Dr Chris Moore, QDPI, Brisbane, QLD  
 Dr Robert Mensah, NSW Agriculture, Narrabri, NSW  
 Dr Ho. T. Dang, NSW Agriculture, Narrabri, NSW  
 Mr Ertong Wang, QDPI, Brisbane, QLD.

#### AIM

*Helicoverpa armigera* remains the most important pest in Australian cotton and also the most resistant pest to different insecticide groups. Semio (signalling) chemicals that may impact on pest behaviour from refuge crops and cotton cultivars will be isolated and their effects as either oviposition repellent/attractants or of feeding deterrent/stimulants will be tested. The promising candidate compound(s) will be extracted, purified and identified, then formulated for use as stand-alone products or together with others for IPM. The use of these chemicals might be as spray on cotton crop, in refuge or in combinations of effective methods.

#### OUTCOMES

During our preliminary screening, an unidentified plant species (referred to as Plant X) was found most effective in deterring oxi position by *Helicoverpa* spp. and causing very high mortality to larvae .

Initial study indicates that the toxin(s) are present in different plant parts with higher levels located in leaves. *H. punctigera* is most sensitive at second instar larval stage and 100 % mortality resulted in 48 hours.

The promising toxin(s) in plant X and other semio-chemicals in other refuge crops and cotton cultivars will be detected, isolated and tested in laboratory, glasshouse and field experiments in stages in the next phase of the project. Identification of the chemical structure of promising compounds will be undertaken.

**PROJECT NUMBER:** 2.2.07 AC

*Project Title:* Pheromones for occasional pests of cotton

#### STAFF

Mr. Samuel Lowor (Postgraduate Student)UNE, Armidale, NSW.  
 Dr. Peter Gregg UNE, Armidale, NSW  
 Dr. Alice Del Socorro UNE, Armidale, NSW.

#### OTHER STAFF & COLLABORATORS

Dr Chris Moore, QDPI, Brisbane, QLD.  
 Mr Dan Alter, UNE, Armidale, NSW  
 Mr. George Henderson, UNE, Armidale, NSW.

#### AIM

To investigate the development of Pheromone lures for sporadic or occasional cotton pest species such as cutworms and rough bollworms.

Pheromones for the key pests of cotton, *Helicoverpa armigera* and *H. punctigera*, have been available since the late 1970's. They have been widely used in research and for monitoring these pests. There is, however, very little information about pheromones of other cotton pests. This particularly applies to occasional pest species such as cutworms (*Agrotis* spp.).

It is currently difficult to forecast the abundance of these species. Considerable damage may occur before growers are aware of the problem. Other pests, such as the rough bollworms (*Earias* spp.), are likely to become more important with the expansion of the cotton industry to new areas, especially in northern Australia.

Pheromones have been identified for some species in this genus in south Asia and Africa, and successfully trialed in mating disruption studies. There is, however, no information on the

pheromones of the dominant Australian species, *E. huegeliana*. For these species the project will:

1. Identify the pheromone components produced by calling females, using GC-MS. This will be done by collecting effluvial air, passing it through absorbents such as Porapak or Super-Q, and extracting by solvents or thermal desorption. The contents of pheromone glands will be recovered by cutting the gland from calling females, followed by solvent extraction and GC-MS analysis.

2. Candidate pheromone blends will be formulated by mixing synthetic components in proportions indicated by the analyses, and impregnating them into rubber septa along with anti-oxidants. The resulting lures will be tested by flying male moths to them in a wind tunnel and compared to those obtained using live females, or whole pheromone gland extracts.

3. Blends which show potential in these studies will be tested in the field, at times and locations where the adult moths are likely to be present. We will use standard pheromone trap designs such as the canister trap, which is used for *Helicoverpa* spp. Light traps will be used for the noctuid moths, to verify the presence of the target species. Night vision glasses will be used to observe the behaviour of moths around the pheromone traps.

This project is conducted by an overseas PhD student whose stipend is paid by the University of New England. Funds for operating expenses are provided by the CRC.

## OUTCOMES

Outcomes of the work will include pheromone lures for some important, but sporadic and occasional, pests of cotton. We anticipate being able to produce these lures at UNE in sufficient quantity and at reasonable cost for wider trials by growers and consultants at the end of the project.

