science exchange

2009

CRC PLANTbiosecurity

22 – 24 September, Sunshine Coast

The Cooperative Research Centre for National Plant Biosecurity is the central coordinating body for plant biosecurity scientific research across all Australian states and territories. We are a cooperative venture between the following core and supporting participant organisations, established and supported under the Australian Government's Cooperative Research Centres Program.

Our vision...

is to be a world leader in the generation, development and delivery of plant biosecurity science and education.

Our mission...

is to foster scientific collaboration and engage stakeholders to deliver plant biosecurity technologies that will reduce risk to, and ensure sustainability of, Australia's plant industries.

Core Participants

ABB

Australian Government
Department of Agriculture, Fisheries and Forestry

Charles Darwin University

CBH Group Celebrating 75 years

CSIRO

Government of Western Australia
Department of Agriculture and Food

State Government Victoria
Department of Primary Industries

GrainCorp

GRDC
Grains Research & Development Corporation

La Trobe University

Murdoch University

NSW Government
Industry & Investment

Plant Health Australia

Queensland Government

QUT

Saturn Biotech
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SARDI
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Supporting Participants

Charles Sturt University

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Southern Cross University
A new way to think

The University of Adelaide Australia

The University of Western Australia
Achieving International Excellence

CRC Australia

Established and supported under the Australian Government's Cooperative Research Centres Program

Welcome

On behalf of the Cooperative Research Centre for National Plant Biosecurity, we take great pleasure in welcoming you to the 2009 Science Exchange.

The Science Exchange provides a unique opportunity for you to engage with a broad cross-section of plant biosecurity stakeholders including our Board Directors, staff, Science Committee, Participants Committee, PhD students, plant biosecurity researchers, plant industry and government representatives.

The Science Exchange will run over two days and will cover the CRC's future directions and presentations from our research projects in the areas of diagnostic platforms, biosecurity risk, tools for response strategies, managing area freedom and post-harvest grains resistance management. These areas closely align with our five research programs.

A Poster and Exhibition session will be held on the Wednesday evening where we encourage you to nominate your favourite poster for a 'People's Choice Award'. There is no greater compliment than the acknowledgment of your peers! During this session you will also see some interactive displays including climate change models, products from our Education and Training Program and the Plant Biosecurity Toolbox (among other things).

You can also look forward to the Science Committee Awards which will be announced at the Science Exchange dinner on Wednesday evening. The Science Committee play a valuable role in the oversight of our research portfolio and have nominated several project teams in categories such as collaboration, innovation and impact on industry.

While on the topic of awards, our Board Directors will also be nominating people for awards including: 'Best Student Poster', 'Best Science Poster' and 'Best Oral Presentation'. We wish all our researchers the best of luck with the awards which are a reflection of the quality of research arising from our CRC.

Once again, welcome to the 2009 Science Exchange. We're sure you will have a great time and hope you find it an engaging and rewarding event.

Professor John Lovett

Chairman

Dr Simon McKirdy

Chief Executive Officer

Wednesday 23 September 2009 (Mudjimba 1)

Welcome and **Diagnostics Platform Session:** MC Chairman Professor John Lovett			Page
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9.25am – 9.40am	Defining a microbial species: implications for plant biosecurity	Dr Brendan Rodoni	5
9.40am – 9.55am	Digital tools for diagnostics	Dr Gary Kong	6
9.55am – 10.10am	Factors affecting the introduction, distribution, migration and colonisation of Currant-Lettuce Aphid *Nasonovia ribisnigri* (Mosley) Australia	Mr Craig Feutrill (PhD Candidate)	7
10.10am – 10.25am	Beyond ELISA: High throughput plant virus detection via multiplexed bead-based immunoassays	Dr Jill Meldrum	8
10.25am – 10.55am	Morning Tea		
10.55am – 11.10am	The geographical relationships of Bean Leafroll Virus across Australia and the Central West Asia and North African Regions	Ms Mai Hlaing Loh (PhD Candidate)	9
11.10am – 11.25am	Protecting Australia's exports – revision of the genus *Epiphyas*	Ms Bobbie Hitchcock (PhD Candidate)	10
11.25am – 11.40am	Using next generation sequencing methods for phosphine resistance diagnostics development	Dr David Schlipalius	11
11.40am – 11.55am	Grains Post Entry Quarantine – a review	Dr Linda Zheng	12
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12.10pm – 12.25pm	Re-evaluation of Warehouse beetle trapping program using molecular markers	Mr Mark Castalanelli (PhD Candidate)	14
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	Participants Committee Meeting	Ninderry 1 & 2	
5.30pm – 7.00pm	Poster and Exhibition Session	Mudjimba Deck	
7.00pm – 10.00pm	2009 Science Exchange Awards Dinner	Mudjimba Ballrooom	

Thursday 24 September 2009 (Mudjimba 1)

Tools for Response Strategies Session: MC: Board Director Mr Barry Windle			Page
9.00am – 9.05am	Tools for Response Strategies	Ms Jane Moran Program Leader Impact Management Research	
9.05am – 9.20am	Managing biosecurity across borders: an Australian-Indonesian partnership to develop a community management model for the management of EPP incursions.	Ms Ruth Wallace	23
9.20am – 9.35am	An integrative approach to understanding the pest and disease threats to agricultural biosecurity under future climates	Dr Jo Luck	24
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9.50am – 10.05am	Real time spatial – temporal modelling of pest insect dispersal: Can TOPS improve predictions	Mr John Weiss (PhD Candidate)	26
10.05am – 10.20am	Characterising the aphid salivary secretome: the key to developing a Russian wheat aphid preparedness strategy	Dr Owain Edwards	27
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Managing Area Freedom Session: MC: Board Director Mr Chris Richardson			
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11.05am – 11.20am	Trapping to prove area freedom	Dr Olivia Reynolds	30
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12.05pm – 12.20pm	Engineering solutions for plant biosecurity	Mr Les Zeller	34
12.20pm – 12.35pm	Simplifying surveillance for airborne fungal pathogens	Ms Bonny Vogelzang (PhD Candidate)	35
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12.40pm – 1.30pm	Lunch		

Post-Harvest Grains Resistance Management Session: MC: Board Director Mr John Sandow			
1.30pm – 1.35pm	Post-Harvest Grains Resistance Management	Dr Pat Collins Program Leader Post-Harvest Integrity Research	
1.35pm – 1.50pm	Three-dimensional Computational Fluid Dynamics model for free convective flow in grain storages	Dr Ming Zhao	37
1.50pm – 2.05pm	Grain Knowledge Networks	Dr Sharyn Taylor	38
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2.20pm – 2.35pm	Resistance monitoring and protocol development: key components in ensuring the biosecurity of post-harvest grain	Dr Manoj Nayak	40
2.35pm – 2.50pm	Stored grains sampling strategies	Dr David Elmouttie	41
2.50pm – 3.05pm	Developing an ecological basis for managing the threat posed by phosphine resistant stored grain beetles in Australia	Dr Greg Daglish	42
3.05pm – 3.10pm	Post-Harvest Grains Resistance Management Session Summary	Mr John Sandow	
3.10pm – 3.40pm	2009 Science Exchange Summary	Dr Simon McKirdy/Professor John Lovett	
3.40pm – 4.00pm	Afternoon Tea		

Diagnostic Platforms

Defining a microbial species: implications for plant biosecurity

Brendan Rodoni[1,2]

[1]Cooperative Research Centre for National Plant Biosecurity, [2]Department of Primary Industries, Victoria

The genomics revolution is changing our thinking of the microbiological world. Only 15 years have passed since the first bacterial genome was sequenced and novel species are now being identified at a rapid rate. Doubt has been cast on the existence of microbial species among environmental isolates and this problem is particularly acute as millions of microbial species are thought to exist that have not yet been cultivated. Possibly the greatest challenge to the species concept for bacteria has been driven by the recognition that lateral gene transfer (LGT) or horizontal gene transfer, has occurred on innumerable occasions. Evidence is emerging that the rate of LGT is far higher than previously thought and that the role of the 'mobilome' in defining the phenotype of a bacterial species has been underestimated.

Next generation sequencing technologies have produced the most accurate estimate on the abundance and variability of the virosphere. It has been estimated that on average, there are 50 million virus particles per ml of costal seawater with the total number of viruses in the ocean now estimated at greater than 10^{30}. A recent study in the Costa Rican rainforest identified thousands of plant viral 'sequence tags' from the rainforest canopy. It is also becoming more evident that viruses are not just pathogens (parasites) but can also be commensal agents (neither host nor virus benefits or is harmed) and mutualists (both virus and host benefit). These findings are in stark contrast to the known plant viruses (less than 2,000 viral species) of which, only six per cent have been isolated from plants in the wild.

Plant viruses and bacteria have recently been identified as the cause of more than two thirds of the emerging infectious diseases of plants during the period of 1996 – 2002 and it is likely that this trend will continue. The emergence of a global community and an increase in plant microbial discovery in the last 15 years has increased the requirement for countries and regions to protect their farming systems from exotic pests. In addressing plant biosecurity requirements countries need to comply with its international obligations as defined by the World Trade Organization Agreement on the application of Sanitary and Phytosanitary measures and protect crops from emergency plant pests (EPPs) at national, regional and individual farm levels. Currently plant quarantine is based on the presence of the pathogen and not the disease. Trade can also be disrupted by the 'presence of the pathogen', or lack of evidence that a pest or pathogen is 'known not to occur'.

It is becoming increasingly unreliable to base the identification of a microbial pathogen on genome sequence data alone. Accurate definitions and identification of microbial species, pathovars and strains are crucial and demonstration of their pathogenicity is required. It is critical that we only quarantine microbial species that have been shown to cause, or be associated with disease.

About the author:

Dr Brendan Rodoni has twenty five years experience as a plant virologist with a focus on the detection and epidemiology plant viruses of temperate and tropical crops. After completing his honours in plant virology in 1985, Brendan worked for six years with the Victorian Department of Primary Industries (DPI) managing plant certification programs for a number of horticultural industries including strawberries, potatoes and carnations. In 1991, he moved to the University of Technology, Lae, Papa New Guinea and lectured in Plant Pathology, Plant Biotechnology and Crop Science. Brendan Rodoni commenced his PhD as a full time student in 1994 at the Queensland University of Technology and worked on the characterisation and control of Banana bract mosaic virus.

In 1997, Brendan re-joined the Victorian DPI as a Plant Disease Diagnostician working in Crop Health Services unit based at DPI, Knoxfield. His research interests include the detection and characterisation of plant viruses and plant pathogenic bacteria, plant biosecurity, environmental microbiology and plant virus disease epidemiology. Currently, he leads a research and development team (11 staff and students with a collective income of $2.5 million annually) that conduct research, manage pathogen tested schemes and provide a diagnostic service for the Australian horticultural industry.

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Digital tools for diagnostics

Gary Kong[1,2], Amy Carmichael[2,3], Dean Beasley[1,2], Julianne Farrell[1,2], John La Salle[4], and Michael Thompson[2,4]

[1]Queensland Primary Industries and Fisheries, Department of Employment, Economic Development and Innovation, [2]Cooperative Research Centre for National Plant Biosecurity, [3]Queensland University of Technology, [4]Commonwealth Scientific and Industrial Research Organisation

- *The Problem.* We are all aware that globalisation has put added pressure on our borders and requires us to assure our trading partners of our pest status. At a time when we require more not less diagnostic capacity, we are seeing a decline in our human capital as experienced people retire – and more often than not they are not replaced. At the same time our educational institutions are losing teaching capacity and are failing to attract students to the required disciplines. This is a systemic problem, and until we recover our human capital, we will need to do more with less, and resources like *PaDIL*, the *Plant Biosecurity Toolbox*, the *Biosecurity Bank* and *Remote Microscopy* can help our existing people now and into the future.
- *The Solution.* Project *CRC27012* is developing a mix of digital technologies designed to provide the building blocks of future diagnostic information systems. *PaDIL*, the *Plant Biosecurity Toolbox* and the *Biosecurity Bank* are web-based tools that provide users with specific diagnostic information to help them make an identification without resorting to an expert. Remote Microscopy connects pest specimens with experts in real-time via a microscope and internet connection so that an instant diagnosis is possible from almost any location. The interaction with these tools creates an environment of learning and through association with an expert, users improve their diagnostic skills in a personal but informal way.
- *Who will use the tools?* Users will range from inspectors in our ports and at our borders to field-based crop protection officers, to taxonomists and experts in labs. They can be farmers, consultants, policy makers and regulators or just simply members of the public. They may be local or international. These tools excite a wide audience and provide information at a number levels – from taxonomy and general biology to risk analysis and detailed molecular tests.
- *The Future.* Viewed independently, the tools present the user with a simple pathway to solve a diagnostic problem and in so doing, perform the useful biosecurity function of pest identification. Wider access and use of the tools will be enhanced through the application of better digital technologies, such as personal digital assistants, wireless networks, portable remote microscopes, dedicated web portals and organised networks of facilities with agreed standards and processes. Beyond this primary function, people interact with the tools to create an instantaneous log of pest specimens, their prevalence and locations which can then be picked up by analytical databases such as the *Atlas of Living Australia*, that will aggregate and draw on these tools and data to provide a deeper understanding of trends. In this sense, these tools provide the materials for future heuristic models of analysis.

About the author:

Dr Gary Kong is a Principal Plant Pathologist with the Queensland Primary Industries and Fisheries (QPI&F). Gary's research with the Cooperative Research Centre for National Plant Biosecurity (CRCNPB) will contribute to and improve the speed and accuracy of plant pest diagnostic procedures.

Gary has a background in Plant Pathology research and since 1987, has studied foliar diseases of field crops. In particular, he has investigated the genetics of resistance to biotrophic and necrotrophic pathogens of sunflower, studied the evolution and population dynamics of the sunflower rust pathogen and developed disease management strategies using marker assisted selection (MAS) as a breeding tool to pyramid disease resistance genes. In addition, he has managed a large research program within QPI&F consisting of plant breeders, genetic resources and post-entry quarantine facilities.

Gary's current interests include the development of electronic information systems such as databases, web-interfaces and remote diagnostic networks. He represents the CRCNPB on the Sub-committee for Plant Health Diagnostic Standards (SPHDS) which develops and recommends national standard processes related to plant pest diagnostics.

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Factors affecting the introduction, distribution, migration and colonisation of Currant-Lettuce Aphid *Nasonovia ribisnigri* (Mosley) in Australia

Craig Feutrill[1,2], Mike Keller[2], Sandra McDougall[3] and Jianhua Mo[3]

[1]Cooperative Research Centre for National Plant Biosecurity, [2]University of Adelaide, [3]Industry & Investment, New South Wales

Currant-lettuce aphid (CLA), *Nasonovia ribis-nigri*, migrated from New Zealand to Tasmania on low-level jet streams in January 2004 and spread throughout Australia within two years. CLA is primarily a contamination pest which colonises lettuce hearts and rosettes, rendering them unsalable. Like many small winged insects, aphids migrate predominantly via wind and human activity. The timing and distance of their dispersal is influenced by many factors including plant quality, photoperiod, temperature and weather events.

Understanding how such factors interact is critical to determining the size of quarantine zones. To investigate factors critical to aphid dispersal, six, nine-metre fully automated suction traps for sampling winged CLA were built and placed at strategic locations in south eastern Australia. The traps sample 45 cubic metres of air per minute, which is funnelled into a fine mesh cone dropping insects into 70ml jars containing polyethylene glycol. Trap catches are segregated daily, which allows analysis of the effects of temperature, wind direction and run, and rainfall events on aphid numbers. Abiotic factors such as plant water availability, nutrition and ambient temperature can also play a major role in initiating insect dispersal through an increase in the development of alate adults.

Experiments were conducted to determine the effects of varying water availability on alate production. CLA were introduced to caged lettuce plants with low, medium and high levels of water available to them. Ten alates were released onto each plant, and plants were destructively sampled after 10 days at 20° C (one generation of CLA) to determine the numbers of alate and apterous fourth stage nymphs. No significant effect of water availability on the alate development of fourth stage CLA was observed. To discount the breeding predisposition of adult parthenogenetic alate CLA, further split-plot experiments will be undertaken.

About the author:

Mr Craig Feutrill graduated from the University of Adelaide in 1986, majoring in Entomology. Once Craig graduated he worked as a field integrated pest management entomologist for 12 years he then worked in information transfer, however it was still based on entomology. His studies and experience have allowed him to understand the need for quality, accurate information to be used by and for the primary production industries when it comes to pest and disease information. This project linked Craig's desire to undertake and complete a PhD that could contribute to the biosecurity of the Australian primary production industries.

Craig's interests outside of science include sailing, cars, motorbikes and his family. He has sailed competitively for the last 10 years including some blue-water classics. Craig has also been a keen motorcyclist for 33 years. He has ridden motorcycles across the Indian Himalaya three times, done a lap of South America, Morroco and Turkey. In 2010 Craig will be motorcycling around the Dalmation Coast. Craig is also interested in restoring cars and motorcycles. He has a 21 year old daughter at University and an 18 year old son being a professional teenager.

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Beyond ELISA: High throughput plant virus detection via multiplexed bead-based immunoassays

Jill Meldrum[1,2], Kathleen Parmenter[3], Darby Kozak[2], Matt Trau[2], Andrew Geering[3,4], Bronwyn Battersby[1,2]

[1]Nanomics BioSystems Pty Ltd, Australian Institute for Bioengineering and Nanotechnology, The University of Queensland, [2]Centre for Biomarker Research and Development, Australian Institute for Bioengineering and Nanotechnology, [3]Cooperative Research Centre for National Plant Biosecurity, [4]Queensland Primary Industries and Fisheries, Department of Employment, Economic Development and Innovation

Plant viruses pose a significant biosecurity threat to Australia's agricultural industries. Current diagnostics range from symptom based analysis to nucleic acid assays and enzyme linked immunoassay (ELISA) detection of viral pathogens. Whilst ELISA tests are routinely used, it involves many manual handling steps and is limited to a single virus per test. New technologies are therefore required, we describe the next generation of ELISA-like diagnostics, the OptoPlex™ bead-based immunoassay system for high throughput multiplexed screening for viruses in plant tissue. Three economically important potato viruses; *Potato virus Y, Potato leafroll virus* and *Potato virus X* are regularly tested for in certified potato seed schemes. An assay was developed to test for the three viruses in multiplex using the OptoPlex™ system. The detection limits for all three viruses were found to be equivalent to that of single virus ELISA and reduced processing time, handling and reagent quantities. Work is continuing to broaden the assay to include more viruses in the Solanaceae and to target other commercially important crops.

About the author:

Dr Jill Meldrum is a Postdoctoral Research Fellow working jointly at Nanomics BioSystems Pty Ltd, the Centre for Biomarker Research and Development based at the Australian Institute of Bioengineering and Nanotechnology (AIBN) at the University of Queensland. Her current research interests include the development of high throughput bead-based assays for virus and protein biomarker detection using antibodies and antibody like molecules. Prior to her current position Jill completed a PhD studying protein folding at the University of Nottingham in the United Kingdom.

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The geographical relationships of *Bean Leafroll Virus* across Australia and the Central West Asia and North African Regions

Mai Hlaing Loh[1,2,5], Kumari, S. G.[3], van Leur, J.[4], Angela Freeman[1,2], Rebecca Ford[1,5] and Brendan Rodoni[1,2]

[1]Cooperative Research Centre for National Plant Biosecurity [2]Department of Primary Industries, Victoria [3]International Center for Agriculture Research in the Dry Areas, [4]New South Wales Agriculture, [5]University of Melbourne

Cool season food legumes (faba bean, chickpea, lentil and pea) are one of the world's most important staple food crops and can suffer from biotic and abiotic constraints that affect both their yield and phenotypic marketability. Luteoviruses cause some of the most devastating crop losses in cool season food legumes, in some cases up to 95%. These severe yield losses can occur in the Central West Asia and North Africa (CWANA) region, where many of the suspected Luteovirids remain either unknown or uncharacterised. As germplasm is sourced from CWANA areas and incorporated into international resistant germplasm breeding programs, there is a need for improved and more definitive detection methods for Luteovirids. *Bean leafroll virus* (BLRV, genus *Luteovirus, family Luteoviridae*) was first described in 1954 and has since been reported in USA, Europe, Asia, Africa, the Middle East and Australia. Here we report a survey of BLRV in the CWANA region and Australia.

Freeze dried samples were selected from a collection held at the International Centre for Agricultural Research in the Dry Areas (ICARDA, Syria), the samples selected were required to fit the following criteria: (I) previously test positive for Luteovirus using a broad spectrum monoclonal antibody 5G4 (II) sourced from a cross section of different countries, years and plant species and (III) were sampled from independent fields. Of the samples testing positive to Luteovirus 5G4 monoclonal antibody, 76 were positive when using the BLRV coat protein (CP) PCR test. Of these 76 BLRV CP PCR positive samples, only 19 were positive to the BLRV specific monoclonal antibody 6G4. Considerable variation was observed in the 370 bp BLRV CP region that was sequenced between these isolates when compared to the Syrian strain of BLRV; with sequence similarities ranging from 53.2 to 94%. Notably, one isolate testing positive to both serological and molecular BLRV assays only held a 53.2% sequence similarity with BLRV, being more closely related to the Luteovirid *Chickpea chlorotic stunt virus*.

The full length genome sequence of three BLRV isolates of importance to the Syrian/Australian BLRV resistance breeding program (from Horsham, Tamworth and Syria) are being generated and will be used to determine conserved and variable regions of the virus genome. This sequence analyses will be used to:

1. design primers to distinguish between BLRV strains, and
2. identify a possible correlation between sequence and symptom expression on the host plants.

Additional surveys will be conducted in the Wimmera/Mallee and Central New South Wales regions to identify the possibility of geographic influence on BLRV sequence variation and/or conservation. The use and accurate identification of type strains of luteovirid species such as BLRV, are critical for the delivery of virus resistant germplasm by international breeding programs.

About the author:

Ms Mai Hlaing Loh graduated with an Applied Biology and Biotechnology degree at The Royal Melbourne Institute of Technology in 2003. In 2005 Mai Hlaing Loh completed a Bachelor of Agricultural Science (Honours) at the University of Melbourne where she developed a high throughput qPCR diagnostic capability for Plum Pox Virus; also helping to establish a self-contained mobile diagnostics capability for use in quarantine incursions of exotic plant pathogens. Working nationally and internationally, her research has contributed to numerous international publications to date. Currently Mai Hlaing is completing her PhD researching the complexities of the Luteoviridae viruses affecting pulse crops. Her research is based in both Melbourne and Syria.

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Protecting Australia's Exports – Revision of the genus *Epiphyas*

Bobbie Hitchcock[1,2], Dr Andrew Mitchell[4], Dr Marianne Horak[3], Professor Mike Crisp[1] and Dr John Trueman[1]

[1] Australian National University, [2] Cooperative Research Centre for National Plant Biosecurity, [3] Commonwealth Scientific and Industrial Research Organisation, [4] Industry & Investment New South Wales

Epiphyas is a large genus of Australian moths (Family Tortricidae). Approximately 60 species are represented in the Australian National Insect Collection, with 66 names available for 38 of these and the rest undescribed. Our taxonomic knowledge of the genus is limited to Common's (1961) six-page review, without illustrations of adults and containing only a few genitalia drawings.

Five species of *Epiphyas* are known to be widely polyphagous. Of these, *Epiphyas postvittana* (the light-brown apple moth) is a native pest which attacks various fruit crops such as apples, pears and citrus. It is listed as a quarantine threat by many countries, thereby placing restrictions on Australian fruit exports. Research into *E. postvittana* has long been hampered by taxonomic problems involving several similar-looking species.

The majority of *Epiphyas* species are apparently restricted to feeding on Asteraceae.The evidence for this is circumstantial, however, and cannot refute suggestions that among the many undescribed *Epiphyas* species, other pests may be present.

An inventory of Australian *Epiphyas* species and a scientific revision describing them – presented with an emphasis on the phylogenetic position of economically important species and combined with host plant information – should demonstrate which *Epiphyas* species are of concern to horticultural industries. Reliable identification tools, accessible to non-specialists, will remove the threat of unjustified quarantine measures.

The outcomes of the revision, using a morphological approach to species identification and presenting a phylogenetic interpretation based on molecular sequence data, are illustrated and discussed.

About the author:

Ms Bobbie Hitchcock is a PhD Candidate in the School of Biology at the Australian National University and the Cooperative Research Centre for National Plant Biosecurity.

Her supervisors are Dr Marianne Horak at the Australian National Insect Collection, Dr Andrew Mitchell at the NSW Department of Primary Industries in Wagga Wagga, Professor Mike Crisp and Dr John Trueman in the School of Biology at the ANU.

Bobbie has an Honours degree in Chemistry from the ANU and a Bachelors degree in Zoology and Chemistry from La Trobe University in Melbourne.

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Using next-generation sequencing methods for phosphine resistance diagnostics development

David Schlipalius[1,2,3], Andrew Tuck[1,2], Rajeswaran Jagdeesan[2,3], Ramandeep Kaur[2,3], Pat Collins[1,2], Paul Ebert[3]

[1]Cooperative Research Centre for National Plant Biosecurity, [2]Queensland Primary Industries and Fisheries, Department of Employment, Economic Development and Innovation, [3]University of Queensland

Developing a gene-based diagnostic tool for a trait like phosphine resistance presents the formidable task of identifying as little as a single causative nucleotide change present in a highly polymorphic genetic background. The advent of next-generation sequencing methods, such as the Roche GS-FLX system and the Illumina Genome Analyser (GAII) system have made it possible to get very large amounts of sequence data from non-model organisms and specific strains of organisms in a relatively short time. This has made it possible to sequence whole transcriptomes and whole genomes from specific strains and to rapidly scan for polymorphisms that associate with particular traits of interest in any given organism.

We have used this approach to target candidate genes for fumigant (phosphine) resistance in two pest insect species of stored grains, *Tribolium castaneum* and *Rhyzopertha dominica*, one of which has a reference genome and one which previously had almost no genome sequence information associated with it. To date, we have resequenced the genome from selected resistant *T. castaneum*, generating 3.5Gb, or approximately 15x coverage of the genome, in a single sequencing run. We have identified two regions that appear to associate with resistance and are currently working on confirming the candidate genes identified. We have also sequenced the transcriptome (the expressed gene sequences) from resistant and sensitive *R. dominica* and are currently analysing the detected sequence polymorphisms between these strains.

While we have used next-generation sequencing for targeting pesticide resistance, it should be noted that a similar approach could potentially be used to target any trait of interest in almost any organism. Given the speed in increase of sequence data acquisition, in the future traits that differ subtly between strains of diseases or pests such as virulence or disease resistance could be identified with relative ease.

About the author:

Dr David Schlipalius began his PhD at the University of Queensland in 1999 on a GRDC scholarship studying the molecular genetics of phosphine resistance in the Lesser Grain Borer, Rhyzopertha dominica, and produced the first genetic linkage map of that beetle.

David also spent a couple of years working on honeybee genomics as a postdoctoral researcher at Purdue University in Indiana, United States of America. He is listed as part of the Honeybee Genome Sequencing Consortium that published the Honeybee Genome Project and worked on the construction of a detailed genetic linkage map to help define genes involved in behaviour, including the stinging behaviour of Africanised ('killer') bees in the Americas.

Since then he has returned to Australia and the stored grains research field to complete the detailed genetic analysis of phosphine resistance.

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Grains Post Entry Quarantine – A review

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The Australian grains industry, which is valued at an estimated $23 billion per annum, is free of many of the major pests, diseases and weeds that are present in other countries. To maintain the pest-free status of this industry and ensure the competitiveness of Australian grains on a global scale, quarantine activities have been implemented at the border and post-border by the Australian Quarantine and Inspection Service (AQIS) to intercept, mitigate and manage the potential threats of pest and pathogen introduction. These quarantine activities are placed under high demand due to the increase in human population, increasingly intensive agriculture and the increase in global movement of genetic materials.

Currently, over 2,000 seed lines, 500 horticultural cultivars, 500 high risk and 70,000 medium risk ornamental plant lines/cultivars are imported through AQIS on an annual basis. It is estimated that 23 tonnes of wheat germplasm is shipped globally each year as industry demands rapid access to new germplasm to enable global competitiveness.

The current screening and identification of most emergency plant pests (EPPs) on grains in Post-Entry Plant Quarantine (PEPQ) is largely based on visual inspections, which are inadequate when the pest and/or pathogen is present in low levels and/or cause symptomless infections (i.e. seed transmitted diseases). The uncertainty about pests and pathogens associated with many species of imported plants, particularly ornamentals further compounds the problem. There is a critical need for the development of more advanced diagnostic tests that are sensitive, efficient and reliable.

The Cooperative Research Centre for National Plant Biosecurity Post Entry Quarantine (PEQ) Diagnostics project is a collaborative project between Victoria Department of Primary Industries (DPI), Queensland Primary Industries and Fisheries, the New Zealand Ministry of Agriculture and Forestry (MAF) and the New Zealand Better Border Biosecurity (B3) program. The PEQ project was commissioned to address the current gaps in diagnostic technologies employed by AQIS to better protect Australia's plant industries and to develop novel strategies for the detection of plant pest groups and genera.

Research in phase I of the project produced a generic diagnostic test that can reliably detect all members within a group of viruses (the potyvirus genus) and work is underway to apply the strategy to 14 additional virus genera over the next three years. Once validated, assays produced by the research program will be able to detect over 40% of all known plant virus species. This capability is especially important in PEPQ due to the large number of viruses that are tested for and the risk of imported plant material containing undescribed virus species. It is envisioned that this technology will assist plant biosecurity to improve quarantine and management of potential EPPs that threaten the Australian grains industries.

About the author:

Dr Linda Zheng graduated with Honours from a Bachelor of Biomedical Sciences degree which she completed at the University of Melbourne in 2004. Linda's interest in genetics and functional genomics saw her undertake a doctor of philosophy program in Ecology, Evolution and Systematics from the Australian National University, Canberra. During her candidature, Linda investigated the implications of plant virus discovery in the genus Potyvirus on their detection and developed a novel method of designing group-specific universal primers for virus detection. Her PhD studies also introduced her to the field of applied bioinformatics.

Currently, Linda is working on a Cooperative Research Centre for National Plant Biosecurity supported project in Post-Entry Quarantine where she continues to explore the world of plant virus diagnostics. Linda's research interests include applied bioinformatics, virus detection and diagnostics, virus evolution and ecology.

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Developing new tools to detect the troublesome *Tribolium*

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Tribolium castaneum is a significant cosmopolitan pest of stored grains and related products. In order to maximise Australia's grain export we follow a 'zero tolerance' for live insects. However, current methods for detection of an infestation are neither sensitive nor reliable resulting in repeated unnecessary and costly fumigations. This approach is also leading to development of phosphine-resistance in *T. castaneum.*

Here, we describe a novel approach to grain-pest detection based on a platform utilizing highly specific and exquisitely sensitive *Tribolium* olfactory receptors. Firstly, we will take advantage of the newly sequenced genome of *Tribolium* to identify candidate olfactory receptor genes. Secondly, we propose to express these genes in a heterologous expression system and screen against potential ligands identified by a parallel study underway in the CSIRO Entomology. The expected outcome is an identification of a number of specific ligand-receptor pairings capable of detecting presence of *Tribolium* in stored grain. These receptors would ultimately be incorporated as the biological front-end for biosensor-based detection systems being developed at CSIRO and elsewhere.

It is expected that research on *Tribolium* olfactory receptors will facilitate a better understanding of the fundamental principles of insect olfaction, which are currently under debate

About the author:

After receiving his undergraduate training from Jagiellonian University in Poland, Dr sylwester Chyb obtained a Soros Foundation Scholarship to study at the University of Oxford in the United Kingdom (UK). Along with Professor Steve Simpson (now a Federation Fellow at The University of Sydney) he studied behavioural and physiological mechanisms of feeding in locusts, Locusta migratoria.

Sylwester then travelled to the Marine Biological Laboratory in the United States of America (USA) to take part in the Neurobiology Course. He then in 1992 took up a postdoctoral research position in the Department of Entomology at Pennsylvania State University, USA, to continue his research into insect taste physiology with Professor Jim Frazier.

In 1996 Sylwester moved back to the UK to take up another postdoctoral position, this time with Dr Roger Hardie's lab at Cambridge University, where he worked on elucidating the mechanisms of phototransduction in Drosophila.

Sylwester then moved to the Imperial College London, UK, to take up a Lectureship and set up the Laboratory of Molecular Physiology.

He joined CSIRO Entomology Division in 2005.

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Re-evaluation of warehouse beetle trapping program using molecular markers

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The warehouse beetle *Trogoderma variabile* (Coleoptera: Dermestidae) is an internationally significant pest of grain storage structures, packed goods and stored grain. It was first documented in Australia at Griffith, New South Wales in 1977 and later, on the other side of the continent in Western Australia. In 2002 a national trapping program concluded that the number of sites with *T. variabile* had more than doubled since 1992 in some Australian states, indicating a significant spread of the pest. *T. variable* was identified using morphological methods at 66 (42%) of the sites sampled. Phylogenetic analysis using mitochondrial genes Cytochrome oxidase I and Cytochrome B, and the nuclear gene 18S reveal seven native species of *Dermestidae* had been misidentified. The study is part of a research project into the *Trogoderma* group of stored grain pests and includes the Khapra beetle, *Trogoderma granarium*, which is not present in Australia and is regarded as one of the highest risk exotic pests to the Australian grains industry. Studies on warehouse beetle will provide valuable information for development of diagnostic tests for Khapra beetle and how it might spread if it became established in Australia.

About the author:

Mr Mark Castalanelli completed his degree in Molecular Biology and Forensics at Murdoch University with honours. Mark is currently a PhD student with the Cooperative Research Centre for National Plant Biosecurity, research project CRC60046: Khapra Beetle.

Mark is excited about his research into molecular understanding of the family Dermestidae as it is a completely unknown area, so he will be the first to investigate. Mark has been involved in European House borer population studies, erradication programs and molecular diagnostics.

When Mark is not researching he is interested in making homebrew and participating in a variety of sports. He recently mountain biked on part of an ancient aboriginal track for three days.

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Biosecurity Risk

ERATication: The fable of the farmer, the demon and the prophet

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Many moons ago there was a jolly apple farmer. She lived in a small village surrounded by apple orchards, as her parents and grandparents had. The farmer took great pride in her apple business, and was a very prominent member of the village community. One day, her neighbour mentioned a chance encounter with a stranger from a far off land. The stranger too had been an apple grower, and he told a sad tale about a demon that had struck his homeland without warning and destroyed most of the apple trees.

The apple farmer and her neighbour became very concerned. They called a meeting of all the apple growers of the village to talk about the stranger's tale and to take measures to prevent the same fate befalling their community. The head of the village and regional governors were also summoned to the meeting, and a great deal of discussion was had about how best to prepare.

Led by the jolly apple farmer, the group decided to seek help from the local prophet whose predictions had helped local villagers in the past. She told the prophet about the demon mentioned by the stranger, and asked him to advise the village on how best to protect themselves against it.

The prophet stared long and hard into his crystal ball. Eventually he looked up, and with a furrowed brow, he asked the jolly apple farmer to convene another meeting of the concerned villagers so he could tell them what he had foreseen.

The day of the meeting arrived and the group listened earnestly as the prophet spoke. He described a diverse agricultural world outside the village that was plagued not by one, but many different demons of all shapes and sizes capable of causing severe damage to many crops. As it happened, the demon the stranger had spoken of was one of the nastiest. Born of the fire, it had blighted apple crops all around the world but had not yet reached the regions around the village.

As he addressed the group, the prophet used an interactive display to show pictures, graphs and charts so that the group could understand the types of damage different demons could cause. Often, the information was complicated, and he was stopped several times and asked to clarify different points.

After his presentation, the prophet sought the views and experiences of members of the group, and asked how they felt about what he had told them. Together, they compiled a list of the nastiest demons based on their proximity to the village and the ease with which they could be kept out or fought off if ever they appeared.

At meeting's end, the jolly apple farmer was very pleased. Not only had she learned all she needed to know about demons that threatened her apple trees, but she had worked together with the other apple growers and members of her community to protect themselves. Together, they built a resilient industry that continues to thrive to this day.

About the author:

Dr David Cook hails from the Great Southern region of Western Australia. He completed a Bachelor of Economics degree with Honours at Murdoch University in 1995. Between 1996 and 2004 he was employed as a Regional Economist with the Western Australian Department of Agriculture where he worked almost exclusively on invasive species issues. During this period David completed a PhD with The University of Western Australia's School of Agricultural and Resource Economics (1999-2001), and worked as a postdoctoral research assistant at the Wye campus of Imperial College London (2003-2004). In 2005 David moved to Canberra to take up a Research Economist position with CSIRO Entomology, and is a Visiting Fellow at the Fenner School of Environment and Society at The Australian National University.

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If biological invasions are spatially and temporally explicit, why isn't biosecurity risk analysis?

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Australia undertakes Import Risk Analysis (IRA) to determine the phytosanitary risks associated with trade commodities. In order to first demonstrate absence and then estimate probabilities of entry, establishment, spread and impact for potentially thousands of exotic plant pests not currently in Australia, spatial layers are required describing the distributions of existing pests, surveillance and response effort, points of entry (pathways), commodity movements (end use, waste points), transport networks, geographic barriers to spread, soils, climate, host vegetation layers, etc.

Because of the often substantial lag between incursion and detection, the ability to attribute an incursion to a particular trade event also requires data to be time-stamped. We argue that capturing such data layers and running risk analysis from a spatial database platform would allow a more robust, rapid and consistent approach with other distinct benefits. For example, climate matching, population dynamics, economic impact and post-detection hindcast models can be vertically integrated and tested under different scale/time scenarios; surveillance and response activities can optimise resource allocation by improved spatial understanding of risk, and data performance including capture, gaps, value, flow (including feedback loops) and sensitivity can be modelled by abandoning the traditional biosecurity 'continuum' (pre-border, border, post border) and applying small world network theory to biosecurity nodes (e.g. pre-border, border, surveillance, response, diagnostics, risk analysis). Although the feasibility and limits to such an approach need further exploration, it offers a potentially elegant solution to the *Beale Review* conundrum of recommending improved biosecurity data capture and management, but not indicating how this might be done or where effort should be apportioned.

About the author:

Dr Brendan Murphy has completed a PhD with the New Zealand School of Forestry (Canterbury) on the biological control of eucalyptus leaf beetles. He worked for three years as a Senior Advisor with Biosecurity New Zealand where he implemented a national forest surveillance strategy, and spent a year contracting on quarantine issues for a state owned enterprise. Brendan commenced a post-doc in February 2008 with CSIRO Entomology/Cooperative Research Centre for National Plant Biosecurity. Brendan's post-doc is based in Brisbane looking at phytosanitary risk analysis and is supervised by Paul DeBarro and Darren Kriticos.

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The spread of pathogens by plant production nurseries: using *Phytophthora* as a model

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Recent outbreaks of *Phytophthora* species (i.e., *P. ramorum, P. kernoviae and P. alni*) in the United States, United Kingdom and European Union are thought to be caused by the movement ornamental plants and trees through the nursery trade. The rapid spread of these plant pathogens via movement of horticultural products across international or interstate lines, or within state borders, is a direct threat to the biosecurity of these regions. Each of the pathogens listed above have caused enormous, well-documented declines in native forests adjacent to nurseries involved in the sale and distribution of infested plants and plant products. These incursions have had huge economic and political impacts on the nursery industries within these countries. Consequently, governmental regulation in those countries of plant production and movement has increased at federal, state and county level.

In Western Australia (WA), disease due to *Phytophthora cinnamomi* (*Phytophthora* dieback) has spread across wild and urban lands through water, soil and direct root-to-root contact. Dieback in the natural environment is managed through many shire and state-level agencies, as well as volunteer groups, yet no organisation is responsible for monitoring disease within the state due to plant trade, other than the Nursery and Garden Industry of Australia (NGIA) itself.

The NGIA are a self-regulated industry. While they must comply with some regulation by Australian government on the issues of hygiene, such as international import/export regulations as required by the Australian Quarantine Inspection Services (AQIS), the NGIA is a self-imposed entity that creates and enacts their own regulatory practices. Despite strict hygiene protocols and response strategies, nursery conditions are very conducive for disease. Release of *Phytophthora* disease within WA from plants both produced in and out-of-state is highly likely. Additionally, recent studies show that some plants can carry *Phytophthora* diseases without showing symptoms, confounding efforts to exclude unhealthy plants from trade. This study aims to identify the presence of *Phytophthora* species in plants sold from production nurseries in WA.

A set of 20 plants, representing major families of ornamental plants, determined to be commonly purchased and susceptible to *Phytophthora* disease were purchased directly from a major production nursery in WA and brought to the glasshouse facility at Murdoch University. Roots were examined for symptoms of disease, and tested for Phytophthora disease via standard baiting techniques with subsequent plating on selective media. Recovered isolates were identified by sequencing the internal transcribed spacer region of ribosomal DNA. The sampling will be repeated seasonally, and expanded to include other production nurseries in WA. Results will be discussed with regards to implications for nursery policy.

About the author:

Ms Amy Smith is a second-year international postgraduate student at Murdoch University. She received a Bachelor of Science degree from the University of California, Davis in Microbiology in 1999, and spent several years managing a large, active Forest Pathology and Mycology laboratory at the University of California, Berkeley. She is currently studying the potential spread of disease by plant production nurseries in Western Australia. Amy's project will utilize molecular, traditional plant pathology, and modelling techniques to study the epidemiology of Phytophthora cinnamomi as it moves from the nursery environment into native and urban garden landscapes. She hopes her project will bring conservation and biosecurity awareness to the garden industry, government and public, in regards to their use and handling of plants and soil.

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Eliciting expert opinion from experts – some lessons from ecology, psychology and reliability

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Expert opinion can provide a valuable resource for biosecurity sciences. In particular biosecurity surveillance relies on several expert estimates of probabilities such as:

1. a species will enter and survive in transit (along a particular pathway in a given time period)
2. if it does successfully enter an area, that it will establish, and
3. if it does establish, where it will spread to.

Typically such probabilities are difficult to quantify, resulting in qualitative risk assessments, which are limited in their scope for further use. Quantitative estimates of these probabilities would not only improve precision of the risk analysis, but would also provide useful input to statistical designs for surveillance, and therefore of resource allocation for surveillance and monitoring. In this paper we summarise some lessons learnt about achieving more robust and repeatable expert elicitation in the fields of ecology, psychology and reliability. This includes some relatively simple tricks such as the wording and ordering of questions about probability. In addition some effort in formulating the goals and methodology of elicitation are important: considering what aspect of the scientific domain of interest that experts will most successfully quantify; and matching this to a statistical model to capture the expert opinions and their uncertainty. Current research is focusing on the challenging problem of calibrating multiple expert opinions so that their opinions can be combined, mathematically or otherwise. We also note that some software has recently proven useful for automating tedious aspects of the elicitation process, whilst providing instantaneous feedback to experts.

About the author:

Dr Samantha J Low-Choy completed a PhD in Spatial Statistics at the Queensland University of Technology. She has seven years as lead environmetrician in State Government and five years post doctoral research in Bayesian statistics. Sama's previous experience also includes teaching and statistical consulting in a variety of fields. Sama is currently Senior Research Fellow in biosecurity statistics. Her expertise and current interests are tailoring Bayesian statistics to design and modelling in biosecurity, environment and ecology, esp. habitat, detectability, species invasion, ecoregions, and ecological or health impacts. Statistical research interests include, calibrating and combining multiple expert opinions, statistical methods and software for eliciting and encoding expert knowledge

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A method for statistical design of complex biosecurity surveillance systems

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Biosecurity surveillance problems are typically complex, with multiple threats, heterogeneous risk surfaces and arrayed detection methods. Available design techniques do not deal with complexity and instead attempt to reduce it, by designing for single threats by a single detection method, or ignoring statistics and designing to budget or other pragmatic considerations. We were challenged to design a statistically based surveillance system (SS) for a complex application and developed a design method that has potential for broader use.

The context is a high-value island nature reserve where a major industrial development has been approved, contingent *inter alia* on a detection program having power (probability of detection given presence) of 80% for non-indigenous species (NIS) of invertebrates, vertebrates and plants. The method addresses typical design complexity as follows:

- To account for a great range of threats, design SSs for several exemplar species, each comprising several detection methods ('SS components' (SSCs)), including traps, surveys and worker observations.
- Use expert elicitation to address data gaps.
- Calculate detection power of each SSC, for exemplar population sizes of acceptable risk.
- Array the SSCs together, taking account of their individual power and broad cost, into an optimised exemplar SS meeting the 80% power specification.
- Use risk-mapping to narrow the sampling frame and deploy each SS efficiently.
- Overlay exemplar SSs to develop an efficient, integrated SS for all potential NIS.
- Give responsibility to surveillance staff for temporal and spatial deployment at local level, to achieve further risk-targeting.

We designed integrated SSs for each of invertebrate, vertebrate and plan NIS. Implementation has commenced and further desktop and field studies will examine robustness and validity. Designs will be adapted as data are acquired and analysed. We describe the design method and its application in this case study.

About the author:

Dr Peter Whittle is a Principal Research Fellow at Queensland University of Technology, working on the Gorgon project for Chevron to develop and implement a surveillance system design for non-indigenous species on Barrow Island, Western Australia. Prior to this Peter earned a BAgSc and PhD at the University of Adelaide (Waite Institute). He also holds an MBA from the University of Queensland. Peter has worked in applied plant pathology research and services at the South Australian Department of Agriculture (cereal root diseases) and BSES Ltd (sugarcane diseases). At BSES Peter was responsible for quarantine services and this concentration continued with his later work in Biosecurity Queensland, where he managed banana quarantine and the Northwatch project. Peter then became Principal Scientist for the General Manager Plant Biosecurity. He has wide experience in biosecurity science including pest risk analysis, diagnostic systems, emergency response management and surveillance design. Peter is also involved in Cooperative Research Centre for National Plant Biosecurity projects on pest risk analysis, systems modelling and statistical studies.

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Crossing the community-government communication border in managing citrus biosecurity in West Timor, Indonesia

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Biosecurity deals with efforts to prevent, control and/or manage risks to life and health as appropriate to a particular biosecurity sector. In doing so, risk needs to be communicated among all stakeholders. Successful risk communication requires communication and information exchange among government agencies, local communities, and the general public. To find out how risk communication plays an important role in biosecurity management, a study is now on-going in 18 citrus-growing villages throughout the highlands of West Timor, Indonesia. For field data collection, in-depth interviews have been carried out with citrus growers, local leaders, and government officers. Content analysis of the interview transcripts shows that pests and diseases are agreed as causing citrus decline but what make it even worse is the lack of communication between local governments and local communities. Whilst local communities consider that information about pests and diseases should be available for them to be able to take the necessary preventive actions, local governments retain their position that law has been enacted and efforts have been made in the best way possible to prevent incursion. The fact that most destructive diseases of citrus are graft transmissible triggers local communities to urge the government to give them the right to produce grafted seedling for their own use. The local governments refuse, of course, arguing that propagation by commercial nurseries makes inspection more manageable in order to guarantee the produced planting material is free of such diseases. In fact, the lack of appropriate facilities and open attitude to the community prevent the local governments from being able to implement such preventive measures. Involving local communities in the management of the diseases, therefore, is the best available alternative and for this to be effective, the governments should engage in every possible effort to provide the necessary information to enable the community to better use their local knowledge for the management of biosecurity.

About the author:

With an educational background in integrated pest management, Mr Wayan Mudita for more than ten years has been involved in a number of research projects in crop protection, particularly in the semi-arid East Nusa Tenggara. It was during this period that he became aware that in this type of agricultural systems to solve crop protection problems requires sound understanding of the social aspect of the existing system. For example Wayan found that an introduced predator failed to establish not because of unfavourable climate or other physical factors but simply because repeated slashing and burning killed most individuals of the released predator.

Wayan's interest in a multi-disciplinary approach to research has further increased after serving as director of a research centre on environmental research for about seven years. During this period, he engaged in various environmental impact management projects and was involved in the management of many other research projects dealing with complex environmental issues. His PhD research now deals with biosecurity management of citrus in West Timor. In this research project Wayan wants to understand various factors influencing community awareness, knowledge, and management of citrus biosecurity, particularly the threat of the devastating HLB (huanglongbing) disease to citrus production, within the framework of social capital.

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Tools for Response Strategies

Managing biosecurity across borders: an Australian-Indonesian partnership to develop a community management model for the management of EPP incursions

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Australia's proximity to south east Asia, particularly eastern Indonesia which lies along much of Australia's northern coastline, places strategic importance on northern Australia in terms of plant biosecurity. Successful eradication of emergency plant pests (EPP) in large measure depends on the length of time between the initial incursion and its subsequent identification. In this region, regional and remote communities are key drivers in early detection and reduction and management of incursions.

In Australia this means the involvement of Australian Indigenous rangers and enterprise owners whose cultural, social and economic livelihoods are connected to biosecurity and environmental outcomes, while in Indonesia, the local community members are small crop framers. As such, community organisations, and members have an essential role on the management of EPP incursions, and their support is recognised as crucial to achieving success in managing plant biosecurity across any borders. This paper provides an overview of the project, the community-based model for the management of EPP incursions and the partnership that has involved a range of stakeholders in the verification of the model. The model has demonstrated that both processes and structures need to incorporated to biosecurity management; the structures include governance structures in organisations, community groups and associations, mediated by well negotiated and understood processes. An effective model of community management of biosecurity involved identifying the community structures and resources, identifying and working with the community to establish awareness and common problems, identifying a common purpose and developing practical solutions. This paper will also provide an outline of the connected and PhD projects that inform the overall projects and provide a view of the project's plans for the future.

About the author:

Ms Ruth Wallace is the Director of the Social Partnerships in Learning Research Consortium at Charles Darwin University, Darwin, Northern Territory. The consortium was established in 2007 to support and research the interagency and interdisciplinary relationships that enable effective learning in different disciplines, workplaces and training sites.

Ruth's particular interests are related to engaging in research that improves outcomes for Indigenous people, policy and government stakeholders in regional and remote Australia. Ruth's research focus is in vocational education and training (VET) practice and workforce development in regional and remote contexts. She has extensive experience in innovative delivery of VET programs in regional and remote areas across Northern Australia.

Ruth has undertaken research into flexible learning, engaged learning and developing effective pedagogy, materials and assessment for marginalised students. In particular, this work explores approaches that focus on recognising marginalised learners' strengths and developing systems that connect to and value learners' diverse knowledge systems. Her research examines the links between identity and adult's involvement in post-compulsory schooling and development of effective pathways through flexible learning and recognition of diverse knowledge systems.

Ruth lives and works in Darwin in the Northern Territory.

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An integrative approach to understanding the pest and disease threats to agricultural biosecurity under future climates

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Despite increasing knowledge of the predicted impacts of climate change, the potential threats to agricultural biosecurity remain uncertain. In this study, models have been developed to better predict the responses of pest and disease threats to our changing climate. By coupling host-plant physiology, virus and vector population growth and climatic data with projected climate change conditions, we are able to predict individual species responses and shifts to historic geographic ranges. Strengthened by empirical data, these models are intended to be incorporated into plant biosecurity management and contingency planning, forming the basis of integrated scenario-based decision support systems for emergency pest and pathogen management. Current work focuses on developing an innovative spatial modelling environment using the bird cherry-oat aphid (*Rhopalosiphum padi*) which vectors *Barley yellow dwarf virus (BYDV)*. The effect of climate change on aphid feeding behaviour, flight time and synchrony with the crop, virus acquisition and transmission rates and wheat phenology changes and physiological responses are being incorporated.

Experiments in the Australian Grains Free Air Carbon Dioxide Enrichment (Ag FACE) research facility have enabled field based investigations of the effects of elevated (e) CO_2 on wheat pathosystems. Wheat stripe rust *(Puccinia stiiformis)* and crown rot *(Fusarium pseudograminearum)* severity, latent period, fecundity and host resistance was assessed under ambient and 550ppm CO_2. While no effects of the treatment were observed with P.striiformis over two seasons, an increase in *F.pseudograminearum* biomass under eCO_2 has been observed in 2008. Our integrated modelling and field based approach to resolving the likely effects of climate change to plant biosecurity will be presented.

About the author:

Dr Jo Luck is Principal Research Scientist, Plant Microbiology for DPI Victoria. In collaboration with CSIRO, Jo and her team are investigating the responses of pests and diseases of wheat to climate change using an integrative modelling and field based approach.

Jo completed her PhD at the Australian National University and CSIRO Plant Industry on the molecular mechanisms of plant disease resistance studying the flax-rust system. She has over 15 years experience working in molecular plant pathology, with ten years experience specialising in plant biosecurity and is the national expert on Pierce's disease of grapevines.

In 2005, Jo and her team commenced a research project on modelling the impacts of climate change on plant and animal biosecurity and have recently expanded this work to include vector-borne diseases such as citrus greening, Barley yellow dwarf virus, Murray Valley Encephalitis and Bluetongue Virus. In 2007 Jo's team commenced a project on understanding the influence of enriched CO2 on major wheat pathogens in the National Grains FACE Array, located at Horsham, Victoria.

Jo leads the Cooperative Research Centre for National Plant Biosecurity project on the impacts of climate change on plant biosecurity which brings together both the predictive and empirical analysis of the impacts of climate change on plant pests and diseases.

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Development of an eradication strategy for exotic grapevine pathogens

Mark Sosnowski[1,2], Robert Emmett[3], Wayne Wilcox[4] and Trevor Wicks[1]

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Eradication of exotic grapevine diseases can incur significant costs to growers and the industry using current strategies which include complete removal of affected and suspected vines. Alternative strategies need to be developed which optimise efficiency of the eradication process and minimise the economic cost of returning the crop to its previous quality and production levels. The endemic disease of grapevine, black spot *(Elsinoe ampelina)*, was used as a model to develop a drastic pruning eradication strategy for the exotic disease black rot *(Guignardia bidwellii)*. These pathogens have similar biology and epidemiology and inhabit fruit, leaves and shoots of grapevines.

A trial was established in the Sunraysia district of Victoria in 2006 to develop and assess a drastic pruning protocol for disease eradication. The trial comprised four table grape cultivars as blocks and plots consisted of three vines with spacing of at least seven metres between plots. Vines in each plot were either drastically pruned (as described below) or left as controls with standard two-bud spur pruning. All vines were inoculated in spring 2007 and developed black spot leaf lesions and stem cankers by the following summer.

Vines in treated plots were cut off at the crown with a chainsaw in July 2008. All excised material from above the crown was placed in an excavated pit about 25 metres from the trial. The vineyard floor around the treated vines was raked and the debris was placed in the excavated area to be burnt and buried. Soil between vines was disc cultivated to bury any remaining debris. Trunks of the treated vines were drenched with lime sulphur using a backpack sprayer to reduce the likelihood of inoculum developing from any infected debris lodged in the bark.

In December 2008, symptoms were recorded on all control vines and on four of 36 treated vines. On treated vines, each symptomatic shoot grew from the trunk within 20 centimetres of the ground. A bioassay conducted on vine debris sieved from the soil below vines indicated that symptoms on treated vines were caused by inoculum produced from the debris. Monitoring of potted sentinel vines placed strategically within and around the trial site during spring and early summer revealed that there was no spread of disease between plots or from external sources.

As a result of this first simulated eradication, the protocol was modified to include removal of lower shoots and the use of straw mulch on the vineyard floor as a barrier to inoculum spread and to accelerate decomposition of debris. The revised protocol will be applied in the second year of the eradication trial in Australia. Validation of the protocol for eradicating black rot has been initiated in an infected vineyard in New York USA, where the disease is endemic. This research has potential to save the Australian wine industry over $18 million in lost production and vineyard re-establishment if there is an exotic disease incursion.

About the author:

Dr Mark Sosnowski is a Research Scientist with South Australian Research and Development Institution (SARDI). After graduating with a Bachelor of Agricultural Science degree from the University of Adelaide, he commenced working for SARDI in 1997 and went on to complete a PhD in 2002, studying the epidemiology and management of blackleg disease of canola at the Uni of Adelaide.

Since 2003, Dr Sosnowski has been responsible for research on managing eutypa dieback disease in grapevines at SARDI as part of the Cooperative Research Centre for National Plant Biosecurity (CRCNPB) for Viticulture and remains responsible for supervision of current Grape and Wine Research Development Corporation (GWRDC) supported research of eutypa dieback. Currently managing a national CRCNPB project aiming to optimise eradication strategies for exotic plant pathogen incursions on perennial crops, Mark is concentrating his own research on the eradication of grapevine pathogens.

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Real time spatial - temporal modeling of pest insect dispersal: Can TOPS improve predictions?

John Weiss[1,2,3], Michael McCarthy[3] and Simon McKirdy[1]

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Predicting the dispersal of exotic insect pests is critically important in managing and restricting their impact. Insects disperse to resources or hosts that are often highly patchy and variable in distribution and quality. Host selection involves not only choosing the right species of plant, but also selecting an individual plant within that species that is, or will be, suitable for feeding, survival and development. Insects need to detect their host from a distance usually utilising visual or olfactory cues or both. Many phytophagous insects are attracted by greens and yellows, although other wavelengths can also be attractive. By using NASA's Terrestrial Observation Prediction System - Gross Primary Production model (TOPS GPP) to model daily photosynthetic rates of vegetation types for south eastern Australia we hope to measure their suitability to particular pests.

In theory, by combining the daily environmental and climatic parameters (soil moisture, soil type, temperature, light exposure, aspect, etc) with the host's biology, one can predict the photosynthetic rate (in terms of gC uptake/m^2/day) or suitability to a pest of a vegetation type. By then combining this measure of suitability with a pest's biology, climate-based simulations can then predict pest outbreaks and help identify feasible and effective containment or management options.

We will compare TOPS predictive pest dispersal model with models run on a static landuse layer to determine which has better predictive power. The Queensland fruit fly, the Australian plague locust and the Currant lettuce aphid, will be piloted, with the project aiming to produce a more generic template model for other pests.

About the author:

Mr John Weiss has been involved with the control and management of invasive species for nearly 20 years. His work with the Victorian Department of Primary Industries (DPIVic) influenced the decision to undertake his PhD project Terrestrial Observation Predictive Systems and Emergency Plant Pest Incursion Management.

He was particularly attracted to the Cooperative Research Centre for National Plant Biosecurity because of its focus on spatial temporal modelling and risk assessment.

John works at DPIVic's Frankston research centre and lives nearby at Seaford - one of Melbourne's bayside suburbs. He has a Labrador and a Blue Heeler Cross, who love walks on the beach. When he's not walking the dogs, John enjoys fishing, bushwalking and cycling around the Mornington Peninsula wineries.

In 2003 John and his partner Penny took long service leave and spent four months living in Bhutan as World Wildlife Fund volunteers, where he worked with the Ministry of Agriculture to develop a weed strategy.

John has visited Bhutan three times and his goal is to finish is PhD in three years. Once he completes his PhD John plans to go back to Bhutan because according to him, the Bhutanese have Gross National Happiness as the main aim not Gross National Product!

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Owain Edwards[1,5], Feng Cui[2,3,5], Changzhong Sheng[3,5], Bo Zhang[3,4,5], Susan Fuller[4,5] and Gerald Reeck[3,5]

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The primary interface between an aphid and its host plant is its saliva. The protein components of aphid saliva, the salivary secretome, are thought to interact with the plant in a similar manner to those secreted by prokaryotic and eukaryotic plant pathogens. Hence, a primary role of aphid saliva is to condition the plant for successful feeding by avoiding or suppressing plant cellular defences. However, the recognition of secreted aphid salivary proteins by plants also forms an integral part of the plant's resistance response. The Russian wheat aphid (RWA) has rapidly evolved to overcome resistant varieties of wheat deployed widely in the United States of America and South Africa as part of response strategies to this highly-destructive pest.

The aims of our projects on RWA are to:

1. identify the protein components of aphid saliva and determine how these proteins interact with a plant host to allow successful aphid feeding
2. determine how RWA is able to rapidly overcome host plant resistance, and
3. investigate the distribution of virulence traits in endemic and invasive RWA populations worldwide.

Taking advantage of the recently sequenced pea aphid genome, we have used a combined transcriptomics and proteomics approach to identify 65 proteins that have strong evidence supporting their expression and secretion into pea aphid saliva. This salivary secretome from pea aphid shows strong similarities to that of the plant pathogenic nematode *Meloidogyne incognita*. We have to date identified 21 of these pea aphid salivary proteins in Russian wheat aphid. A high level of diversity exists in many of these salivary proteins. High rates of salivary gland gene evolution have been achieved by gene duplication and diversifying selection. Some single copy salivary gland genes are also undergoing positive selection. Future studies will determine the relative frequency and distribution of salivary gland gene diversity in regions where RWA is endemic compared to those where RWA has recently invaded.

About the author:

Dr Owain Edwards is a Principal Research Scientist and Research Program Leader (Invertebrate Genomics and Evolution) at CSIRO Entomology in Perth. In 1986 Owain received his undergraduate degree in Zoology from the University of Guelph, Canada. He completed his Masters and PhD degrees in Entomology from the University of Missouri (1989) and University of California – Berkeley (1994), respectively. After postdoctoral fellowships investigating the genetics of classical biological control at the University of Florida and the USDA-ARS in Newark, Delaware, Owain moved to Australia to study aphid ecology and genetics. Since 2001 Owain's research has focused on aphid-plant interactions, and in particular the molecular interactions between aphids and resistant vs. susceptible host plants. In 2003, Owain joined an international consortium of scientists bidding to sequence the genome of the pea aphid. This bid was finally successful in 2005, and Owain remains an active contributor to, and leader within the International Aphid Genomics Consortium. With the availability of the aphid genome, Owain is now working with collaborators around the world on two major projects: the molecular characterisation of aphid saliva, and the molecular regulation of aphid polyphenism.

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Forecasting spread for rapid response

James Bennett[1,2], Michael Renton[1,2], Art Diggle[2,3], Fiona Evans[2,3], Nancy Schellhorn[2,3]

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Rapid response protocols are essential to minimise the cost of incursion of a new invading pest/disease organism. A key element of a rapid response is an effective surveillance strategy, which relies on the ability to forecast the spread of the organism in the environment in which it was found. Currently rate of movement is estimated semi-quantitatively, on a case-by-case analysis, to guide containment or eradication programs. These estimates have sometimes been found to be inaccurate after the fact due to lack of quantification of the way that an organism's characteristics affect its spread.

This project aims to improve the accuracy of spread forecasting by developing a general rapid response system to rapidly summarise the spread characteristics of any new invading pest/disease organism. Instead of splitting species into specific functional groups, our framework will consider a multi-layered functional group approach where each organism is grouped separately for different types of characteristics, i.e. layers. In the event of an incursion the new organism will be characterised within each of these layers. The resulting combination of groupings will then form a multi-layer functional characterisation of that organism.

The system will provide a parameterisation for spread models for any invasive organism. I will present the initial prototype design for the multi-layered characterisation system along with some preliminary test output.

About the author:

Dr James Bennett completed his PhD in 2008 at the Royal Melbourne Institute of Technology (RMIT), Melbourne. His background is in applied mathematics. The title of his PhD thesis is 'Mathematical Analysis of Film Blowing' where he analysed the highly complex film blowing process. Film blowing is a process where thin sheets of polymer are manufactured. A couple of applications (of many) of the thin films produced are uses in the packaging industry and plastic bags. James highlighted the presence of an interior layer in the radial profile of the film along with an initial boundary layer arising through small elastic effects. He applied a mixture of heuristic techniques with the method of matched asymptotic expansions to obtain approximations to the highly nonlinear differential equations that govern the process. The approximations were then used as initial approximations for an iterative Galerkin finite element numerical scheme to obtain numerical solutions.

James Bennett accepted a Cooperative Research Centre for National Plant Biosecurity supported position at the University of Western Australia as a post doctoral research associate in the School of Plant Biology in April 2009. His current research interests are in improving the accuracy of spread forecasting by developing a general rapid response system to rapidly summarise the spread characteristics of any invading pest/disease organism. Other areas of interest are applied mathematics and statistics, in particular, singular perturbation problems.

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Managing Area Freedom

Trapping to prove area freedom

Francis De Lima[1,6], Olivia Reynolds[2,6], Shirani Poogoda[1,6], Catherine Smallridge[3,6], David Madge[4,6], Jianhua Mo [5,6]

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Quantitative data was obtained over two seasons (2007-2009) to assess whether a dynamic and strategic trapping approach provides an equal or higher level of statistical confidence as the current static and passive grid to prove area freedom from the Queensland fruit fly (QFF), *Bactrocera tryoni* (Froggatt) and Mediterranean fruit fly (MFF), *Ceratitis capitata* (Wiedemann). The benefits of a more efficient monitoring system are reduced costs for trap deployment and eradication and lower environmental impacts. Data was collected (fly numbers and host phenology) weekly through the year but fortnightly in winter in Western Australia (WA), New South Wales (NSW), South Australia (SA) and Victoria. Besides field research in WA and NSW, data was mined from historical outbreaks in area free zones of NSW, SA and Victoria.

In Western Australia, MFF traps were deployed (in towns and on farms) in four geographical locations at 48 sites (2007-08) and 59 sites (2008-09). A 200 metre zone around each site was mapped and fruit phenology recorded at each trap check. The sites were chosen based on previously known population densities Donnybrook (>2/flies/trap/week); Manjimup (<2/flies/trap/week); Pemberton (0/flies/trap/week); and in Kununurra area free zone (0/flies/trap/week). A higher percentage of MFF were invariably captured in dynamic versus static traps.

In NSW (2007-08), QFF traps were deployed and host phenology recorded in three towns Cootamundra (30 sites), Junee (30 sites) and Gundagai (30 sites). In the 2008-09 season, the town Ganmain (24 sites) located near a zero QFF area replaced Gundagai. In the 2007-08 season, there were higher QFF numbers in January to early March. In Cootamundra dynamic traps had more fruit flies than static traps. At other sites there was no difference. From late March - June fly numbers differed between sites with Cootamundra < Junee < Gundagai. In May static traps caught more flies than dynamic traps in Junee. Cootamundra had higher catches in dynamic traps compared with static traps for pome fruit. There were no differences in Gundagai. In 2008-09, QFF numbers were particularly high from mid-February until mid-April in Cootamundra and from mid-January until mid-March in Junee. In Ganmain, densities were low and flies were only trapped for eight weeks. In all towns except Junee, more QFF were trapped in dynamic as opposed to static traps.

QFF data was mined in the risk reduction zone (RRZ) in the Riverina from 2003-2008 from the NSW Department of Industry and Investment (DII) Pestmon database giving a total of 486 record sets in citrus, pomefruit, stone fruit, and other trees. To stratify regional effects the trapping areas included fourteen towns in inland NSW.

In SA, data mining of QFF outbreaks was done to record surrounding properties for infested fruit within a radius of 200m of each outbreak site. These data were combined with data extracted from overhead imagery for 10 QFF detection sites to compare areas where detections resulted in outbreaks with areas where detections did not result in an outbreak.

In Victoria, QFF trapping data extracted from the Victorian fruit fly database 'Flybase' was combined with the results of seasonal fruit tree phenology and geographical information (water courses/bodies) for more detailed analysis.

About the author:

Dr Olivia Reynolds is a Research Scientist with Industry and Investment New South Wales (NSW). Olivia is responsible for post-production issues pertaining to fruit fly, with particular emphasis on the Queensland fruit fly, Bactrocera tryoni. She is also involved in projects looking at the role of silicon in induced plant defences. Olivia has led a number of projects in NSW, including one which aims to optimise sterile fruit fly releases for improved market access and another national project which aims to optimize a strategic trapping system to provide area-wide freedom from fruit flies, CRC30039: Fruit Fly Area Freedom. Another involves the role of silicon in tri-trophic interactions (plant-pest-natural enemies). Olivia also collaborates on two other projects, one which is looking at developing female lures for fruit flies, CRC30022: Female Lures: Fruit Fly Trapping, and one of which will lead to specific management recommendations on optimal environmental conditions, release rates and release locations for sterile fruit flies. Olivia also supervises a number of postgraduate students including PhD CRC60106: Fruit-Fly Parasitoid.

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You can't have a conversation with a brochure! Fostering community engagement principles to bring about change in local biosecurity practice

Paul Royce[1,2]

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Typically, the provision of biosecurity information to the Australian general public does not stem much further than formal, uncomplicated and one way methods of communication such as websites, road signage and brochures. While growing attention has been afforded to biosecurity and its global impact on human activity, let us hope that Australia's response to such a challenge extends beyond simply developing snazzier websites, billboard sized road signs and a wider distribution of more colourful brochures in a multitude of different languages.

Although the existing rhetoric assumes that biosecurity management requires a 'whole of community' approach, there is very little evidence to suggest that local population groups have the capacity to undertake, or should be responsible for, such tasks in the current biosecurity climate. One of the fundamental flaws in this thinking presupposes that members of any particular community have equal access to biosecurity related information, that this information is equitably distributed according to cultural, linguistic, social, economic and physical attributes, that biosecurity information is equally adopted as new knowledge, that community members are motivated to translate new knowledge into action and that community members have equal access and opportunities to participate in local decision making processes and therefore social change. Unfortunately, this is not the reality in most Australian communities. This seminar presentation reports on the findings of an extensive qualitative research study in a north Australian agricultural region, which indicate that applying the principles of community engagement to biosecurity management may be a far more effective way to raise biosecurity awareness and bring about social change and transformation that is relevant, meaningful and authentic to communities and its members.

About the author:

With some 18 years experience in the community services sector, Mr Paul Royce has held a number of grass roots and senior management positions in youth work, community development and community services, mostly within a Western Australian local government setting.

In early 2005, Paul moved to the Northern Territory to take up a lecturing position at Charles Darwin University and upon being offered a Cooperative Research Centre for National Plant Biosecurity scholarship, moved with his partner to Kununurra in the north east corner of Western Australia to undertake a PhD, 'Biosecurity through Community Engagement'. Using the OrdGuard Regional Biosecurity Plan as a case study, Paul's research focuses on understanding more effective ways to introduce biosecurity strategies using the principals of community engagement.

Paul has a Bachelor of Social Science (Youth Work) from Edith Cowan University, a Masters in International and Community Development at Deakin University and was the Chairperson of the Local Government Community Services Association of Western Australia between 1999 and 2004.

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Improving the integrity of exotic plant pest surveillance data with hand-held (PDA) computers

Rob Emery[1,2]

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Australia remains committed to World Trade Organization agreements, Sanitary and Phytosanitary agreements, the *International Plant Protection Convention* and international sanitary and phytosanitary measures and recognises the need for quarantine plant pest surveillance data of the utmost integrity is essential to support area freedom negotiations.

With most of Australia's agriculture produce exported, securing and maintaining market access is critical as is the need to demonstrate freedom from certain plant and animal pests and diseases. Surveillance is an important tool for securing market access and accordingly exporting countries now need to provide accurate, credible evidence to confirm absence (i.e. known not to occur) for pest freedom status.

In the past, nearly all field collected surveillance information was recorded manually to paper reducing the rate of capture, integrity, conformity as well as security of the data. This Cooperative Research Centre for National Plant Biosecurity (CRCNPB) project focused on the development of pest surveillance data collection software and hardware using hand-held computers or PDAs (Personal Digital Assistants). This approach provides chain of evidence control, increases the volume of data collected as well as its integrity through relational databases and seamless data transfer to corporate systems.

CRCNPB PDA software developed with Visual CE was successfully trialled during the 2007 post-border detection of Khapra beetle by providing evidence of complete eradication via 1,273 trap inspections. This achievement was supported by GPS-located traps, digital voice navigation itineraries, digital time and date stamps, field printed barcode labels, site imagery all in a single hand-held unit.

New PDA hardware and software is under development by the CRCNPB for use in other pest surveillance activities. These include, hazard site pest surveillance, stored grain fumigation monitoring, grain insect resistance testing and fruit fly phenology studies.

About the author:

Mr Rob Emery has over 30 years of service with the Western Australian Department of Agriculture and Food where he has investigated broad spectrum economic entomology. For the last 25 years he has led the Department's Stored Grain Research Group primarily monitoring and managing phosphine resistance. His interest in Information Technology came through entomological database development and delivery over the Internet. Mr Emery's current research is supported by the Cooperative Research Centre for National Plant Biosecurity with whom he has projects on handheld computers for field surveillance data collection, remote diagnostics, Internet plant pest surveillance and grain insect resistance.

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Hierarchical Bayesian models: Epidemiology and data for defining pest extent

Mark Stanaway[1,2,3], Robert Reeves[1,2] and Kerrie Mengersen[1,2]:

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Area freedom cannot be proven; only its probability can be estimated. Current informal approaches to delimiting pest extent rely upon expert ecological interpretation of presence / absence data over space and time. Hierarchical Bayesian models provide a cohesive statistical framework that can formally integrate all of the available information from both epidemiology and data. They allow inference to be made on the probable extent of pests by breaking down surveillance systems into a series of simpler component models.

A model is presented to demonstrate the hierarchical Bayesian approach to estimating area freedom. The method involves constructing an observation model for the surveillance data, conditional on the hidden extent of the pest and uncertain detection sensitivity. The extent of the pest is then defined by a dynamic invasion process model that includes uncertainty in epidemiological parameters. Markov chain Monte Carlo techniques allow the probable extent of the pest to be estimated from the combined observation and process model, given the surveillance data and stated uncertainty.

The methodology can assist decision-making across a range of plant biosecurity surveillance activities including early detection, market access and incursion response. Outputs include not only the estimate of area freedom, but also the likely location of pests and epidemiological characteristics of the invaders. Risk maps derived from these models can be incorporated into GIS systems and updated as new data arrive. The tools developed by this project can be used by biosecurity regulators to direct surveillance towards current risks and to assess the performance of surveillance programs.

About the author:

Mr Mark Stanaway's PhD is on Hierarchical Bayesian Models for Evaluating Emergency Plant Pest Surveillance

For the past eleven years, Mark has worked with Biosecurity Queensland and was pleased to take the opportunity offered by the Cooperative Research Centre for National Plant Biosecurity's PhD scholarship to tackle some statistical problems to improve surveillance programs. Mark's PhD is building on his undergraduate degree in population ecology and postgraduate study on modelling insect incursions.

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Engineering solutions for plant biosecurity

Les Zeller[1,2]

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This abstract and presentation describes an evaluation of engineering technologies relevant to Australian biosecurity that is currently being used and developed by United States Department of Agriculture (USDA) engineers, United States Geological Survey (USGS) scientists and microbiologists at Virginia Polytechnic Institute and State University.

A USDA engineer Dr Jeff Drake based in New Mexico has developed a Robotic Automated Pest ID (RAPID) system which identifies and sorts insects using robotics and image recognition and analysis technologies. This system currently can identify insects at the genus level with accuracies approaching 95%. Small operational changes to the system were discussed during my visit which will significantly improve this accuracy to almost 100% and increase the possibility of identifying to the species level in the future. The image recognition component of this system is well developed and is versatile enough to incorporate new or varied identification characteristics depending on the species of interest. Some work is still required to fully automate the sample delivery system but this will depend largely on the required application. The engineer involved is keen to collaborate with the Cooperative Research Centre for National Plant Biosecurity to further develop this technology. Equipment has also been developed to investigate the hyper spectral signature of insect images as an identification method. Again this technology is well developed but further research is required to identify species that have spectral signatures that are statistically different.

USGS Microbiologist Dr Dale Griffin from Tallahassee in Florida is using unmanned aerial vehicles (UAV) to collect dust samples which are transported from North Africa's Sahara desert across the Atlantic Ocean by the tropical trade winds. The belief is that this dust is impacting on the health of humans and ecosystems in the Caribbean and the Americas. The sampling system utilises commercially available technologies to collect samples but the research team is investigating a more effective and efficient venturi system to create the required vacuum for sampling. The use of a venturi system may prove to be an ideal solution for the Cooperative Research Centre's Flying Spore Trap project as it requires no electrical power.

Associate Professor Dr David G. Schmale III of Virginia Polytechnic Institute and State University in Blacksburg is also using UAVs as the platform for collecting spores for his research in food safety and plant biosecurity. He developed spore traps that are operated manually using free channels of the plane's remote controller to initiate and terminate spore collection. This allowed control over sampling height and duration which with knowledge of air speed enabled quantification of spore concentrations. Future work will progress an electrostatic sampling method being developed by Dr Raymond Schneider of D&S Electrostatic Samplers based in Los Angeles.

About the author:

Mr Les Zeller is a Senior Research Engineer, Emerging Technologies, for Queensland's Department of Employment, Economic Development and Innovation. He has 28 years experience in the design, development and application of engineering technologies for agricultural research. Les has completed a Bachelor of Applied Science in Physics and a Master in Engineering.

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Simplifying surveillance for air-borne fungal pathogens

Bonny Vogelzang[1,2,3], Eileen Scott[2], Kathy Ophel-Keller[3], Moin Salam[4] and Jenny Davidson[3]

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Plant disease surveillance is important for early detection of incursions, monitoring disease status during eradication programs, and to demonstrate that an area is free of a particular pathogen, for trade purposes. Surveillance for plant pathogens currently relies on detection of symptoms by suitably skilled personnel. The difficulties of distinguishing diseases based on symptoms, and of timing surveillance to coincide with symptom expression, can result in new pathogens not being detected until they are already widespread. In epidemiological studies, monitoring has relied on symptom expression in crops or trap plants. However, there may be logistical challenges in assuring a timely supply of trap plants, and the amount of inoculum may be underestimated if conditions are suboptimal for disease development. More efficient surveillance techniques for plant pathogens are therefore needed. The combination of air sampling and PCR-based diagnostics allows fast, reliable, accurate, sensitive and specific detection of air-borne fungal pathogens. This project aims to apply quantitative PCR techniques, in combination with air sampling, for detection of air-borne fungal plant pathogens, and to determine the strengths and constraints of these tools in relation to plant health surveillance.

Methodology has been developed for PCR-based detection and quantification of fungal pathogens from air samples, using three model pathogens which occur on pulse and oilseed crops grown in rotation with cereals in South Australia. The model pathogens are *Leptosphaeria maculans*, causal agent of blackleg of canola, *Mycosphaerella pinodes*, one of a complex of pathogens causing Ascochyta blight of peas, and *Ascochyta rabiei*, which causes Ascochyta blight of chickpeas. These organisms were chosen because their ascospores are reasonably distinctive morphologically, real-time PCR tests are available for them, and airborne ascospores of the three organisms are expected to be at different concentrations in the field.

The technique for extracting DNA prior to PCR has been optimised and the PCR-based methodology has been proved to be both sensitive and specific to the three model pathogens. Results of monitoring for the three model pathogens in 2008 indicated that the PCR-based tests were in good agreement with microscopy, and there was broad agreement with trap plant data. The methodology enabled truthing of epidemiological models for blackleg and blackspot. Valuable epidemiological information was obtained as it was possible to use this methodology to gather data during months when trap plants cannot be grown. For example, numerous ascospores of *M. pinodes* were released on rain days in December and January, indicating that fruiting bodies of the fungus do not require further maturation before releasing spores, even after a period of over a month with no rain. As expected, spore trapping and trap plants both failed to detect air-borne ascospores of *A. rabiei*, which are normally absent, or present at only very low levels in South Australia.

About the author:

Ms Bonny Vogelzang has been working in the biosecurity field for the past 15 years. Her PhD is allowing her to draw on her work experiences and knowledge while building further her research skills.

Previously, Bonny worked for Australian Quarantine Inspection Service and the Queensland Primary Industries and Fisheries (QPI&F) and also freelanced. Her recent work with QPI&F was on early warning surveillance and the Northwatch program.

Bonny says she has always been interested in the big picture of biosecurity.

"I think maintaining Australia's pest free status is important - exclusion is the first and often the most environmentally and cost-effective strategy for maintaining plant health and therefore keeping down costs to agriculture and the environment."

Taking on her PhD has meant a move from sunny Cairns to Adelaide and the chance to reconnect with friends and family in her childhood city. (She misses the warm weather, but is enjoying the South Australian environment, vegetation and landscape).

Climbing St Mary's Peak in the Flinders Ranges is one of her proudest personal achievements - pretty good for someone without a good head for heights.

Professionally, her work in assisting to set up a quarantine service in the newly independent East Timor was another big high.

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Post-Harvest Grains Resistance

Three-dimensional Computational Fluid Dynamics model for free convective flow in grain storages

Ming Zhao[1,2], Wei He[1,2] and Liang Cheng[1,2]

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Understanding of transient internal distributions of pressure, temperature, moisture and fumigant concentration and their interactive processes are vital essential for improvement on grain storage management in a quantitative manner. Most of research initiations have focused on inter-granular convection and diffusion phenomena inside the grain bulk only, which may not be sufficient to tackle problems with complex bunker configurations and boundary conditions, especially for unsealed sheds and bunker storages in current industry practices. In this research, attempts have been made to characterise wind flow around and inside bunker storages under various climate conditions. It is anticipated that the results from the simulation of flow outside of the storages can serve as input boundary conditions for modelling transient internal distributions of pressure, temperature, moisture and fumigant concentration in grain storages.

A transient three-dimensional Computational Fluid Dynamics (CFD) model is developed to simulate heat and moisture transport in grain storages. The air flow in grains is simulated by solving the Navier-Stokes equations with Darcy terms and the terms of inertial resistance. The convection-diffusion equations of temperature and moisture are solved numerically. The governing equations are discretized using a streamlined-upwind finite element method (FEM). A parallel FORTRAN code is developed base on MPI (Message Passing Interface). Numerical results of air flow, temperature and moisture distributions in a typical grain storage are presented.

About the author:

Dr Ming Zhao was awarded his PhD degree in 2003 in the Department of Civil and Hydraulic Engineering, Dalian University of Technology, China. From 2002 to 2005 he worked in the Dalian University of Technology as a postdoctoral fellow. Since 2005 he has been working in the School of Civil and Resource Engineering, The University of Western Australian successively as a Research Associate, Research fellow and Research Assistant Professor.

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Grains Knowledge Networks

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The Grains Knowledge Networks (GKN) project is a multi-disciplinary project with its major aim being the development of an effective knowledge exchange strategy to reduce the development of phosphine resistance in insects of stored grain. Evaluation and development of knowledge exchange networks will ensure that new messages and practices can be easily and rapidly adopted by the industry.

This project is made up of three main components:

1. the identification and evaluation of networks that exist within the grains industry for the delivery and exchange of information
2. identification of mechanisms to deliver this information, and
3. identification of economic factors that influence phosphine resistance management practices.

Understanding the process and development of an effective knowledge exchange strategy is complex and for this reason a number of review documents and strategies are being developed by the project team including:

- *'Review of knowledge transfer strategies'* – The first step in the development of an effective knowledge exchange strategy is evaluation of the process of transferring knowledge from the holder to the user. This document reports on a change management model looking at the types of extension activities and impact of each on intended levels of change. Practice change will happen when knowledge of past extension activities are combined with current stakeholder issues.
- *'Communication plan for management of phosphine resistance'* – This document provides an outline of communication activities to be undertaken during this project. Activities undertaken within the GKN project will link closely with delivery of information through the Grains On-farm Biosecurity Program, the Grains Research and Development Corporation Grains Storage Extension project and other grain storage projects operating in the CRCNPB.
- The GKN project has assisted with finalisation of the *'Strategy to manage resistance to phosphine in the Australian Grain Industry'* – This document was developed in consultation with industry and contains recommended practices for fumigations with phosphine in specific storage types (e.g. small and large scale sealable storages, bulkheads, bunkers).

Based on the recommendations provided by the 'Strategy to manage resistance to phosphine in the Australian Grain Industry', an end-user benefit-cost analysis was undertaken that provides insight into factors involved in decisions behind phosphine management practices. This tool was designed to be used to assist at the time of purchase of a new silo and compares sealed vs. unsealed and aerated, as well as chemical costs and installation costs. As part of the GKN project, key messages will be promoted to industry using Grains Biosecurity Officers in Western Australia, Queensland, Victoria and South Australia. These officers will serve as a mechanism for the delivery of future knowledge exchange and stakeholder engagement within the grain industry.

The GKN project, together with the national Grains On-farm Biosecurity Program (and Grains Biosecurity Officers) operate within Biosecurity Planning and Implementation Program at Plant Health Australia.

About the author:

Dr Sharyn Taylor joined Plant Health Australia (PHA) as a Program Manager (Biosecurity Planning and Implementation) in 2007. In this role, she is responsible for Industry Biosecurity Plan development and review which includes the identification of key pest threats and risk mitigation strategies such as the preparation of contingency plans and implementation of farm biosecurity practices for each of PHAs plant industry members. Sharyn is also responsible for the identification and implementation of improved plant pest surveillance measures for plant industries and governments to assist with domestic and international market access and early detection of key pest threats. Within PHA, she manages the Grains On-farm Biosecurity Program, a large initiative with Grains Biosecurity Officers in four regions that improves awareness of biosecurity and surveillance for key pest threats in the grains industry.

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Phosphine resistance modelling: the right genetics is crucial

Glenn Fulford[1,2]

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The most common and effective pest control methodology for insect pests in grain storage is fumigation with phosphine gas. However the emergence of strong levels of resistance to phosphine threatens its continued use. Linkage analysis and molecular techniques have provided strong evidence that resistance is conferred by two genes on separate chromosomes. For the insect pest *Rhyzopertha dominica* (the lesser grain borer) resistance in individuals homozygous for both resistant genes has been determined to be well over 250 times greater than those with no copies of the resistance genes, whereas there are weaker resistance factors of 2.5 times to 30 times if the resistance genes are present in only one of the two locations, depending on which location.

This paper describes the development of a mathematical model for the population genetics for *Rhyzopertha*, for fumigation under a given concentration of phosphine gas. The mathematical model incorporates two-locus genetics, with nine genotypes, modelled by differential equations. Using the model, some different fumigation strategies are investigated; for fumigation switched on for a given period and switched off for a given period. The two-locus model is compared with a single-locus model by aggregating the genotypes in the two-locus model. While this model is still in the preliminary stages and requires more rigorous validation, it does clearly demonstrate much different qualitative outcomes for the two-locus model compared to an a one-locus approach. It is argued that accounting for the correct genetics is crucial.

About the author:

Dr Glenn Fulford is a Senior Lecturer within the School of Mathematical Sciences at Queensland University of Technology (QUT). His research interests encompass mathematical modelling in ecology and epidemiology, industrial mathematics and low Reynolds number physiological fluid dynamics. Prior to working at QUT he has been a lecturer at the University of New South Wales (Australian Defence Force Academy campus), a Research Scientist at AgResearch in New Zealand and a software engineer at GeoScience Australia. Glen has a keen interest in mathematical modelling and has published three textbooks in this area. He is currently supervising a PhD project in the modelling of phosphine resistance in grain pests.

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Resistance monitoring and protocol development: key components in ensuring the biosecurity of post-harvest grain

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Management of resistance to fumigants and contact insecticides in key stored grain pests plays a significant role in maintaining the biosecurity of Australia's $7 billion grain industry. These materials are crucial to the grain industries ability to supply the 'insect-free' product demanded by both domestic and export markets. A major drawback, however, with this strategy is the threat of resistance in pest species.

Two key components of managing this threat are a national resistance monitoring program and the development of treatment protocols to combat resistance. The monitoring program provides information on the frequencies and levels of resistance in time and space and also early warning of the development of new resistance. A statistically robust, nationally agreed protocol is followed, which runs concurrently at three research laboratories representing each of the grain growing regions in Australia (Northern, Southern and Western). Information gathered is used to advise industry of regional and national trends and to identify where eradication, containment or other resistance management activities can be implemented.

The other key component is the development of effective treatment protocols to control newly emerged resistant biotypes. For example, once a new phosphine resistance is detected, a purified 'worst-case resistant strain' is established in the laboratory and fumigation protocols (including concentration, exposure period, and temperature parameters) is developed. Close collaboration with industry ensures that the laboratory based protocols are validated through field trials before their adoption.

A successful outcome from this research program has been the management of strong resistance to phosphine in the lesser grain borer. This resistance problem was first detected in 2000 and posed a serious threat to post-harvest grain biosecurity. The latest threat is the emergence of very high-level resistance in flat grain beetle populations in central storages. Research is in progress to tackle this biosecurity problem.

About the author:

Dr Manoj Nayak is a Senior Research Entomologist with the Food Protection Team of Queensland Primary Industries and Fisheries (QPI&F). His main research interests include development of grain protectants, phosphine efficacy, resistance management and integrated pest management in processed food.

Manoj joined QPI&F in 1995 as a visiting scientist after immigrating from India. Prior to that he completed his tertiary degrees at Delhi University: a Masters in Zoology with specialisation in Entomology in 1988; a Master of Philosophy in 1989 researching the nutritional and reproductive physiology of the rice grasshopper; and a PhD in 1993 on ecology and epidemiology of several arthropod disease vectors. At QPI&F, Manoj started his research on psocids, which were emerging as new pests in the grain storages at the time and there were no management options available. By the early 2000, Manoj had established several chemical strategies to manage psocids and was also involved in developing such strategies in China and Vietnam through a collaborative Australian Centre for International Agricultural Research project. Over the last 13 years, he has also been involved in several Grains Research And Development Corporation projects both as a lead researcher and project leader.

Manoj's expertise on psocids and resistance management has earned him keynote invitations at international conferences such as the 9th International Working Conference on Stored Product Protection (Brazil, October 2006) and the XXIII International Congress of Entomology (South Africa, July 2008). In recognition of his sound publication profile and critical reviewing skills Manoj is frequently invited as a peer-reviewer to review research papers submitted for publications in several international journals including Journal of Stored Products Research, Journal of Economic Entomology, Pest Management Science, Journal of Applied Entomology, Pesticide Biochemistry and Physiology, Australian Journal of Entomology, Bulletin of Entomological Research and Environmental Entomology.

Manoj is a member of the Entomological Society of Australia (served as the Regional Councillor), Entomological Society of Queensland and Society of Chemical Industry (UK).

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Stored grains sampling strategies

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Stored product pests are a significant problem for the domestic and export grain industry. Substantial costs are associated with treatment of infested grain lots, commodity loss due to insect damage and rejection of shipments by importing countries. Quarantine regulations of importing countries often dictate that grain commodities entering a country must be free from live insects, as stored product insects are seen as a significant biosecurity risk. In order to minimise the risk of commodities being exported with live insects, sampling strategies are employed along the production and supply chain, to detect pests prior to shipment. The aim of our project is to identify currents sampling strategies used for detection of insect pests and proof of area freedom in export grains commodities.

To date, the project has focused on acceptance sampling methods for bulk grain storage. Similar to acceptance sampling programs in other industries, sampling strategies in grains have typically assumed a homogeneous distribution of insect pests throughout grain bulk. Stored product insects however, are known to respond to microclimatic conditions in grain storage facilities, with insects clustering in different areas of bulk grain commodities. Here we consider an alternative approach to acceptance sampling of bulk grains that unlike other acceptance sampling methodologies takes into consideration insect behaviour and biology and the potential for a heterogeneous distribution of insect pests.

About the author:

Dr David Elmouttie is a Research fellow with the Cooperative Research Centre for National Plant Biosecurity in the School of Natural Resource Sciences at Queensland University of Technology. David is a quantitative ecologist whose previous research has focused on understanding pest-resource interactions in complex ecological systems. David has worked in a number of agricultural systems including grains, sugar, rice, and maize. David's research is currently focussed on the development of a flexible statistically based sampling strategy for the detection of post harvest grain storage pests in the Australian export grains industry.

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Developing an ecological basis for managing the threat posed by phosphine resistant stored grain beetles in Australia

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Phosphine resistant forms of stored grain beetles are a critical biosecurity issue for Australia, and elsewhere.

Knowledge of the ecological processes contributing to the development and spread of resistance is fundamental to managing this problem. Understanding has, however, derived largely from laboratory population studies with relatively little information from the field.

This paper describes the key results obtained from the initial phase of research on the ecology of two major pests, the lesser grain borer *(Rhyzopertha dominica)* and the rust-red flour beetle *(Tribolium castaneum).*

A priority is to quantify the dynamic pattern of distribution and abundance of each beetle species across the rural landscape. A long-term trapping program is under way in two grain growing districts, in Queensland and New South Wales. The traps are baited with species-specific pheromones and located near silos, in paddocks and in native vegetation.

The lesser grain borer adults are widely distributed away from grain storages in the two study areas, and are more abundant there than expected from North American results. The rust-red flour beetle is aggregated around grain storage, which is consistent with results from the United States of America.

Other research is in progress to test if individual beetles interact with key aspects of their environment in a species-specific way. For example, attempts are being made to characterise beetles emigrating from infested silos by intercepting individual adults as they leave the storage and evaluating them in the laboratory. Results to date show that *R. dominica* females have mated before emigrating, that both sexes typically live for three months at 25°C, and that females captured in this way are capable of producing several hundred adult progeny during this time without further mating.

Results such as those described in this talk will provide ecological insights into the evolution and spread of phosphine resistance and therefore contribute to the development of effective resistance management.

About the author:

Dr Greg Daglish is a Principal Research Scientist with Queensland Primary Industries and Fisheries (QPI&F) in the Queensland Department of Employment, Economic Development and Innovation. Greg's research with the Cooperative Research Centre for National Plant Biosecurity (CRCNPB) will lead to better management of insect pests of stored grain through research on the ecology of key pests and improved phosphine fumigation of grain.

Greg has a strong interest in postharvest control technologies including the practical application of knowledge of resistance and insect ecology. He has been working in this field since 1988 and his experience includes field and laboratory evaluation of phosphine fumigation and grain protectants, genetics and fitness of phosphine resistance, and ecology of grain insects. He has led ten national and international projects for the Grains Research and Development Corporation, Australian Centre for International Agricultural Research, and recently the CRCNPB. Greg has been an active member of National Working Party on Grain Protection since 1999, including leadership of the grain protectants committee. Greg has published widely on stored grain entomology, and been invited to speak and chair sessions at conferences such as the International Working Conference on Stored Product Protection and the International Conference on Controlled Atmosphere and Fumigation in Stored Products. He has served on the editorial board of the Journal of Stored Products Research since 2005 and became Regional Editor (Australia and Asia) in 2007.

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Scientific Posters

An economic analysis of surveillance and quality assurance as strategies to maintain grain market access

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The aim of the project is to analyse the economics of insect pest biosecurity in the Cooperative Bulk Handling grain storage and transport network in Western Australia (WA) using a systems based modelling approach. The research will include the following:

1. Analyse the current system of pest surveillance and control in WA grain storage and transportation system using a mathematical programming model based on Brennan (1992).
2. Determine how the system of surveillance and control should be modified in response to changes in market requirements, the possible emergence of phosphine resistance and changes in fumigant and pesticide regulations.
3. An analysis of the design of farm quality assurance schemes such as the current system run by Cooperative Bulk Handling (CBH) namely Better Farm IQ, in terms of incentives for biosecurity on farm.
4. Using the transport model present an analysis of the optimal response to the emergence of phosphine resistance
5. Using the transport model, analyse the implications of farmers participating in the Better Farm IQ scheme.

The results of this research will allow the grain industry in Western Australia to account for the costs, benefits and risks associated with different spatial patterns of grain movements between farm and port in the Kwinana region.

About the author:

Ms Hoda Abougamos graduated from the University of Commerce (Egypt) with a degree in Accounting. She then went on to complete her Diploma in Environmental Economics and her Master Degree in Research. Hoda's Masters studies were concerned with Economic Instruments and how they can be implemented to solve agricultural problems (over-irrigation for plants etc). Finally, Hoda is completing her PhD at the University of Western Australia. Her PhD involves examining exporting grains and the problems associated with this procedure, including grain transportation and storage. Biosecurity is a major concern of her research.

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Sensing the troublesome *Tribolium*

Kelly Bailey[1,3], Richard Glatz[1,3] and Sylwek Chyb[2,3]

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Tribolium castaneum is a stored-food pest of significant importance throughout the world. The presence of these and other insect pests in stored grain facilities compromise Australia's export potential since most markets with which we trade specify a zero tolerance for live insects. Current visual methods for the detection of an infestation are not sensitive or reliable, so unless the produce has recently been fumigated with phosphine, pests are assumed to be present and the grain is re-treated. This leads to continued selection pressure for phosphine resistance and increases the costs of pest management in the grains industry.

A reliable, sensitive, quick and cost-effective method to detect pest infestations would be highly desirable and aid in development of treatment thresholds allowing targeted fumigations, lowering the risks of resistance development in pest strains. Sequencing of the *T. castaneum* genome has recently been completed and has revealed a large family of putative olfactory receptor genes. It is within these genes that we are searching for one that encodes a target receptor with which to construct a sensing platform capable of highly sensitive detection of the infesting beetles. To do this, we aim to express and isolate pheromone receptors, which the insects themselves use to detect low levels of volatile chemicals released by one another.

Methods such as quantitive-PCR will be employed to expose candidate gene sequences involved in pheromone communication, followed by behavioural and physiological approaches such as RNAi silencing and cell-based assays (e.g. calcium imaging), which will be investigated to determine protein function. It is envisioned that research into insect pheromone receptor systems will not only demonstrate the feasibility of using them as a potential biorecognition element in a biosensor device, but would additionally aid in our overall understanding of the mechanisms involved in invertebrate olfaction.

About the author:

Dr Kelly Bailey recently completed her PhD through the Department of Biochemistry at the University of Adelaide, but carried out her research at CSIRO Division of Molecular and Health Technologies, in Adelaide. Kelly's PhD involved developing assay and array technologies for G-protein coupled receptors (GPCRs), a group of important cell surface receptors, both physiologically and pharmacologically. This involved techniques such as protein expression, purification, fluorescent assay development, and protein immobilisation. Although Kelly was based in Adelaide, she carried out many of my experiments interstate, at CSIRO sites located at Parkville and Clayton, as well as overseas, in the Laboratory of Biosensors and Bioelectronics at the Swiss Federal Institute of Technology, Zurich. This work led Kelly into her current position at SARDI Entomology, and her involvement in the Cooperative Research Centre for National Plant Biosecurity project investigating olfactory receptors (thought to be somewhat similar to GPCRs) of a cosmopolitan pest beetle, Tribolium castaneum, and the utility of these receptors as a recognition element within a sensing device capable of detecting their presence.

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Establishment of a national reference laboratory for *Trogoderma* diagnostics

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The Khapra beetle, *Trogoderma granarium* Everts (Coleoptera: Dermestidae) is one of the most destructive pests of grain products. It has been nominated among the *'100 World's Worst Invasive Alien Species'* and is listed by Plant Health Australia as one of the top five biosecurity threats to the Australian Grains Industry. Australia by definition does not have Khapra beetle. An incursion could lead to costly eradication efforts. Non-Khapra beetle countries enforce strict quarantine restrictions on imported commodities from Khapra beetle countries. Misidentification with closely related *Trogoderma* species has the potential to seriously compromise Australian grain exports.

Diagnostically the Khapra beetle can only be reliably identified by a limited number of highly skilled taxonomists. There are over 120 described *Trogoderma spp.* worldwide two of which are serious pests, a further four are of minor significance. In Australia there are over 50 described *Trogoderma spp.* and many more remain undescribed. None of these are pests, but can accidentally get into grain stores and be misidentified. Suspected *Trogoderma* specimens found in grain products are usually the larvae or larval skins which are difficult to diagnose morphologically. Adult specimens are usually scarce and damaged and need expert dissection for identification. Due to their similarity, warehouse beetle (*T. variabile Ballion*), already in Australia, or native *Trogoderma spp.* could be mistakenly identified as *T. granarium*, or could mask the early detection of Khapra beetle.

The project aims to establish a national reference laboratory for Khapra beetle diagnostics. Several disciplines are involved including morphological taxonomy, molecular phylogenetics and diagnostic imaging. We plan to obtain validated *T. granarium* specimens from a biogeographically diverse range of countries and develop tests that reliably differentiate it from related species known to occur in Australia. Type material held in collections in the United States, European, Asian and Indian subcontinent institutions will be reviewed. Validated specimens will be keyed out using existing keys, photographed and screened using molecular diagnostic techniques. A nationwide *Trogoderma* trapping program is being organised to survey the status of *Trogoderma variabile* and the related native *Trogoderma spp.* in Australia. Phylogenetic and phylogeographic profiles for Trogoderma are being developed in associated PhD project *(CRC60046)*. The molecular diagnostic tests will undergo further refinement and validation as part of the National Diagnostics Laboratory accreditation process. The project's diagnostic imaging laboratory will be used to photograph validated specimens. The use of 3-D enhanced images of morphological characters of the standard used in PaDIL will assist the development of Lucid keys and provide a web-based identification tool for *Trogoderma* made available through the *Plant Biosecurity Toolbox*.

This research will help Australia to rapidly detect Khapra beetle, as well as demonstrate its area of freedom status. Establishment of an accredited facility addresses the 'International importance of accredited diagnostic laboratories using accepted diagnostic procedures' as written in the *International Standards for Phytosanitary Measures* (ISPM 27).

About the author:

Dr Oonagh Byrne, BSc (Zoology), MSc (Biotechnology), PhD (Agriculture). Oonagh's current research is on the establishment of a National Reference Laboratory for Trogoderma and related Dermestids, CRC20137 at the Department of Agriculture and Food WA (DAFWA). Prior to taking up the position at DAFWA, Oonagh played a key role in transferring pea weevil resistance into Australian field pea cultivars, developing a molecular marker protocol for field pea resistance screening, and in publishing on the genetics of pea weevil resistance in field pea (GRDC, ARC). Oonagh holds an adjunct Research Fellow position at the University of Western Australia.

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Factors affecting the dispersal of fungal pathogens: Chickpea ascochyta blight as a model

Steven Coventry[1,2], Jenny Davidson[1,3], Moin Salam[4] and Eileen Scott

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Exotic fungal plant pathogens pose a threat to Australian agriculture. Some of the most devastating fungal pathogens are transported by rain splash, wind dispersal or a combination of both. The transport of fungal pathogens via rain and wind makes containment and eradication difficult. *Ascochyta rabiei*, causal agent of ascochyta blight of chickpea, is a wind/rain borne pathogen already present in Australia. A. rabiei, therefore, provides a suitable pathogen for modelling the potential spread of an exotic fungal pathogen dispersed by wind and rain.

Field trials and laboratory studies were conducted to examine key environmental factors influencing the short distance (rain splashed) and long distance (wind borne) distribution of spores.

Laboratory experiments were conducted to investigate the effect of wind speed (m/s), rain splash (ml/m) and a combination of the two factors on the dispersal of conidia in a purpose-built wind and rain tunnel.

A model for determining the spread of rain and wind-borne pathogens was developed for ascochyta blight based on the spatiotemporal model for simulating the spread of anthracnose in lupin fields (1). The data collected from the field trials and laboratory experiments were entered as the model parameters. The adjusted parameters produced a model output in Mathematica™ that best fit field disease observations.

The outcome of this work is a model calibrated with experimental data and tested with field observations for accuracy. Weather data are entered into the model and pathogen spread is predicted by graphical output showing disease occurrence in the field. The number of conidia produced per lesion on each of the cultivars will be estimated, to add more information to the model. When fully developed, the model will provide a basis for predictive models for exotic plant pathogens. It will also facilitate improved management of disease through forecasting, and more precise application of fungicide and timing of crop sowing.

About the author:

Mr Steven Coventry's PhD is looking at factors affecting short and long distance dispersal of fungal pests and he is using Chickpea Ascochyta blight as a model. He is studying at the University of Adelaide where he received his honours degree in agricultural science degree, majoring in integrated pest management.

Steven chose the Cooperative Research Centre for National Plant Biosecurity because it related so well to his undergraduate program and he's particularly interested in biosecurity because it deals with more than one aspect of pests and diseases. It has a whole system approach.

Steven enjoys living in Adelaide as he believes, "It doesn't have the hustle and bustle of Melbourne and Sydney but it has beautiful hills, great wine, the best beer and people are generally friendly and work hard."

He likes to be active on his weekends and regularly does martial arts training.

Steven believes biosecurity research is important for Australia's future to stop incursions of pest and diseases that may threaten our ecosystems and because it will mean economic sustainability. This will in turn lead to high quality products which are highly competitive the world over.

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Grains industry contingency and surveillance planning

Stephen Dibley[1,2], Jo Slattery[1,2], Sharyn Taylor[1,2]

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The Industry Biosecurity Plan for the Grains Industry (Grains IBP), developed in 2006 and reviewed in 2009, provides a framework for biosecurity activities within this industry. Within the Grains IBP, exotic plant pest threats were identified and ranked based on the likelihood of entry, establishment and spread together with the potential economic impact of their introduction to Australia. Pests with the highest overall risk were selected for the development of contingency plans and surveillance planning activities undertaken within this project. This work builds upon the Grains IBP to raise levels of biosecurity preparedness in the industry.

Contingency plans provide basic information for use in the development of response plans, the documents developed in response to exotic pest incursions. Each contingency plan is pest-specific, outlining basic pest biology, impacts of introduction, required surveillance, a summary of available diagnostic tests and facilities and known control or eradication methods. By collecting and summarising this information, contingency plans potentially assist with more rapid eradication, containment or management mechanisms following exotic pest detection, helping both deliverers and beneficiaries of the emergency response.

Within both this, and a previous Cooperative Research Centre for National Plant Biosecurity and Grains Research and Development Cooperation project, a total of 30 pest-specific contingency plans will be developed for exotic pest threats likely to have the highest impact should they become established in Australia. In order to develop these plans, entomology and plant pathology experts, as well as experts in the Australian quarantine system, have been engaged to assist in development of these plans.

To further assist with preparedness for high priority pest threats, the National Grains Surveillance Plan has been developed providing the framework to help ensure that Australia can justify its area freedom claims for exotic pests of the grains industry. Under this framework, the current project is developing pest-specific surveillance plans for three key exotic high priority insect pest threats. It is anticipated, these plans will assist in determining minimum surveillance data requirements for pests of high importance to the grains industry. In addition, they will provide direction to industry and government stakeholders in relation to the surveillance and awareness activities and resources needed to provide an appropriate level of confidence of early detection, therefore increasing the likelihood that they may be eradicated or contained should they enter Australia.

Development of these contingency and surveillance plans for the Australian grains high priority exotic plant pest threats will ensure Australia is better prepared to respond to exotic pest incursions.

The authors would like to acknowledge the Grains Research and Development Corporation for providing funding for this project.

About the author:

Dr Stephen Dibley has a PhD from the University of Newcastle, completed in 2005, on molecular investigations into the role of hexose/H+ symporters in sugar accumulation of the developing tomato fruit. He joined Plant Health Australia in 2008 and has worked on Industry Biosecurity Plans, implementation of on-farm biosecurity programs and contingency planning. Recent activities have included work on surveillance planning, farm biosecurity manuals and pest-specific awareness material.

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South African Citrus Thrips in Queensland: What are the risks?

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The South African Citrus Thrips *Scirtothrips aurantii* (SACT) was first discovered in Australia on Mother of *Millions Bryophyllum delagoense* (MoM) at Sherwood, Queensland in 2002. The presence of SACT in Australia was a cause for biosecurity concern as in its native range it is highly polyphagous and a controlled pest of both citrus and mango. Surveys in SACT infested areas failed to detect the insect on these or any other plants save MoM and preliminary lab studies found collected thrips only able to survive and breed on MoM. While this has led to suggestions that the Queensland population of SACT might be a cryptic species or specialised host race, morphological and molecular taxonomy has found no difference between the MoM feeding thrips present in Australia and those collected from citrus in South Africa. A recent, more in depth study has found that SACT in Queensland can indeed successfully feed and reproduce on mango, certain varieties of citrus, as well as a variety of other plants including some native species.

Complicating the situation, MoM is a serious weed of grazing areas in New South Wales and Queensland. SACT has a visually dramatic impact on MoM, with infested plants appearing scarred and stunted. While the actual impact of the insect on the plant is still being studied, it is the only current biological control option available to grazers, and it has been intentionally spread in parts of southern Queensland and northern New South Wales. Given the conflicting interests of various stakeholders in Australia, it is important not only to attempt to simply determine whether the SACT in Queensland is polyphagous, but also to what extent its polyphagy poses a risk to Australian agriculture.

There are other highly polyphagous species of *Scirtothrips* known to be pests on various crop species, some of these are already present in Australia, and two, *S. dorsalis* and *S. albomaculatus*, are controlled pests of mango and citrus in Queensland. These pest species also have a broad recorded host range consisting of plants in many families, however all species have a similar requirement no matter the host; new flushing growth to oviposit and feed on. Leaves and buds are damaged by these activities, but the extent of damage is dependent on thrips density, which in turn is dependent on how quickly populations are able to build up on the new growth. By comparing SACT performance on various hosts to those of *Scirtothrips species* with known pest status, a clearer outline of the possible threats this new insect presents to Australian horticulture should be determined. Additionally, by investigating a number of *Scirtothrips* species in concert, it is hoped more can be learned about how these insects select and interact with their hosts, and what plant traits might play a role in protection from infestation.

About the author:

Mr Brian Garms is a Ph.D. Student at the Australian National University. He is interested in entomology, agricultural systems, biological control/IPM, and invasion biology. Brian's thesis involves studying native insects to better understand how introduced insects might be expected to perform, either as biocontrol agents or as potential pests.

Two systems Brian is studying involve native herbivorous insects feeding on introduced weeds. This represents a novel interaction and understanding whether the native insects have evolved in any way to take advantage of a new resource is of great interest. While testing for evidence of host race formation or other types of rapid evolution, the preference and performance of various insect populations on differing hosts must be determined, and this information is of value in its own right. It may indicate there is indeed a real difference between these plants and might suggest a direction to work in a biological control program. It is also of interest to determine whether the native insects themselves could be useful biological control agents. Looking at what damage native insects do to introduced weeds provides a useful null model for considering an exotic biocontrol agent as well. If native insects on a weed do a certain amount of damage, then any biocontrol agent of a similar feeding niche would have to exceed that damage to be effective.

Brian's third and final system involves South African Citrus Thrips, a recently introduced insect that has the potential to be a serious pest of citrus and mango. For the last six years it has only been found on a particular weed in Australia, but in its native South Africa it feeds on a number of economically important crops. While the populations of the insect present in Australia have been shown to feed on these and other plants in a lab setting, it is unclear what risk this insect poses to Australian agriculture. However, other closely related thrips species in Australia already cause damage to some of these crops, and thus provide the chance to put the potential threat of this insect into context. By broadly using the same conceptual and experimental tools as outlined above, I plan to compare the host performance of local species of known pest status to an introduced species with an unknown status.

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Development of biosecure packaging for transport of emergency plant pest samples

Barbara Hall[1,2], Pauline Glocke[1,2] and Alan McKay[1,2]

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There are significant risks involved with movement of diagnostic samples potentially containing emergency plant pests (EPPs), within Australia and internationally. This has recently been recognised by the proposed changes to the United Nation regulations for transport of dangerous goods, which will include quarantine plant pathogens in the definition of infectious agents for the first time. In addition, a review of the Subcommittee for Plant Health Diagnostics (SPHDS) highlighted the difficulties with packaging and transport of test samples between states as an issue that must be resolved to ensure the development of a successful national diagnostic system for EPPs within Australia.

This project aims to address these issues by developing packaging standards that can be used for the secure and legal containment and transport of these samples for diagnosis. Specifications are being developed for suitable packaging standards to comply with United Nations regulations for the transport of plant, soil and insect samples that will maintain integrity during transport, be readily available to all users, and meet all legal requirements. In addition, the project aims to help raise awareness on the importance of correctly packaging possible or confirmed EPPs for transport. This paper outlines the evaluation process being undertaken to develop the specifications, aimed at using suitable, readily available and accessible packaging.

About the author:

Ms Barbara Hall is a plant pathologist with over 30 years experience in diseases of Horticultural crops, and currently works as a Senior Research Scientist within the Horticulture Pathology Unit of the South Australian Research and Development Institute (SARDI). Barbara manages the Horticultural diagnostic service and the Quarantine unit within SARDI, overseeing the Post Entry Plant Quarantine Facility and ensuring the campus is compliant with AQIS requirements for receiving and handling quarantine material. Barbara coordinates and supervises research projects undertaken within the unit, and manages the South Australian component of several national vegetable pathology projects, both broad acre and greenhouse.

Barbara has been involved in biosecurity for many years, more recently as a member of the sub-committee for Plant Health Diagnostic Standards (SPHDS) which develops and recommends national standard processes related to plant pest diagnostics. She is the chair of the Diagnostic Standards Working Group, which promotes and facilitates the development of diagnostic protocols for EPPs and endemic pests of national significance.

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Estimating the diagnostic accuracy of tests used in emergency plant pathogen surveillance

Nichole Hammond[1,2,3] and Dominie Wright[1,3]

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Field validation of diagnostic tests is an important component of developing national and international diagnostic protocols. In biosecurity, diagnostic tests are routinely used in surveillance activities and testing for compliance with phytosanitary standards to demonstrate freedom from plant pests. Validation of diagnostic tests includes optimisation of the assay, demonstration of the assay's performance characteristics and determining the 'fitness' of the test (consistency and accuracy) for the particular purpose for which it is being used.

Performance characteristics of the test commonly considered include the limit of detection (analytical sensitivity), and cross-reactivity (analytical specificity). Determining the accuracy of the diagnostic test for use with field samples is possibly more important for use in activities designed to demonstrate freedom. This is defined as the ability of the test to correctly predict the infection status of the unit being tested. In clinical sciences, the most commonly used measures of test accuracy are diagnostic sensitivity and specificity, and the positive and negative predictive values of the test. Although not a new concept in plant pathology, diagnostic accuracy is often not quantified in the development of new diagnostic tests.

In this paper, we report on two studies conducted to estimate the diagnostic sensitivity and specificity of the traditional sieve-wash test and the new enhanced diagnostic protocol for detection of *Tilletia indica* (Karnal bunt) and other *Tilletia spp*. The first study used the traditional 2x2 contingency table using samples of known disease status (*T. indica*), or a 'gold standard' test, to classify the samples. The second study used Bayesian methods to estimate the test accuracy in samples of unknown status, or in the absence of a 'gold standard', using established *Tilletia spp.* in harvest samples as a model. The results of these studies provide estimates of the accuracy of the enhanced diagnostic test and thus the appropriateness of the test for use as a surveillance tool in demonstrating and managing area freedom.

About the author:

Ms Nichole Hammond is undertaking a PhD at Murdoch University, Western Australia, and is supported by the Cooperative Research Centre for National Plant Biosecurity. Her PhD research is looking at methods for evaluating surveillance and surveillance tools for demonstrating freedom from plant pathogens.

Prior to undertaking her PhD Nichole worked for the Western Australian Department of Agriculture and Food for eight and a half years in a number of biosecurity related fields within the plant pathology section, including diagnostics, surveillance, pest risk analysis and plant health policy.

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Investigating plant pests just got fun! Plant biosecurity in school classrooms

Melanie Hay and Kirsty Bayliss

Cooperative Research Centre for National Plant Biosecurity

What would plant biosecurity look like in a primary school or secondary school classroom?

The Cooperative Research Centre for National Plant Biosecurity (CRCNPB) school education program was established in response to reports that indicate decreasing student enrolments in science courses at all education levels, and the increasing perception in school-aged students that science is 'too hard' or 'boring' and 'not relevant'.

The CRCNPB has developed resources for primary (5 – 12 year olds) and secondary school (13 - 18 year olds) classrooms with the aim of engaging students in science and raising awareness of plant biosecurity.

Schools have been teaching students about plants, invertebrates and diseases for a long time, however the CRCNPB has created engaging resources that combine learning about traditional science content within the real world context of plant biosecurity.

An overview of the CRCNPB's school education program will be provided along with samples of our school resources.

About the author:

Ms Melanie Hay has been passionate about science since uttering her first word, 'why?'. This passion led to degrees in Science and Secondary Education and then, into the classroom, where she enjoyed sharing her love of science with students. As the CRCNPB Education Officer, Mel continues to enjoy teaching and learning science.

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Susceptibility of Australian native plant species to *Phytophthora ramorum*

Kylie Ireland[1,2], Daniel Hüberli[2,3], Bernard Dell[2], Ian Smith[4], David Rizzo[5] and Giles Hardy[2]

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Phytophthora ramorum is an invasive plant pathogen causing considerable and widespread damage in nurseries, gardens and natural woodland ecosystems of the United States of America and Europe, and is classified as a Category 1 emergency plant pest in Australia. It is of particular interest to Australian plant biosecurity as, like *P. cinnamomi*; it has the potential to become a major economic and ecological threat in areas with susceptible hosts and conducive climates.

Research was undertaken in California to assess the pathogenicity of *P. ramorum* on Australian native plants. 69 test species within 24 families were sourced from established gardens and arboreta, and selected based upon provenance from areas of climatic suitability for *P. ramorum* as well as ecological and economic importance. Susceptibility and sporulation potential was tested using detached leaf and branch assays. All species showed some level of susceptibility, and some asymptomatic infection was recorded. Disease incidence and severity were greater during the summer, and when the leaves were wounded. Highly susceptible host species included *Banksia attenuata, Eucalyptus nitens, E. delegatensis, Isopogon cuneatus, I. formosus, Leptospermum scoparium. Olearia argophylla, Sollya heterophylla, Tasmannia lanceolata, Pittosporum undulatum,* as well as all the conifers and grasses tested, showed consistently low susceptibility. Some branch susceptibility was observed, with only the juvenile branches of *E. leucoxylon* more susceptible than those of the positive control *Rhododendron* 'Colonel Cohen'. *Sporulation* was recorded for a few species, particularly on juvenile foliage. Results of the studies will be discussed in relation to their implications for disease entry, spread and development of an epiphytotic within an Australian biosecurity framework.

About the author:

Ms Kylie Ireland is a Cooperative Research Centre for National Plant Biosecurity (CRCNPB) PhD student based at Murdoch University in Western Australia. Kylie chose to do her PhD with the CRCNPB for the support and networking it could provide, as well as the scholarship, learning and travel opportunities.

Kylie decided to do her PhD to improve her scientific analysis and networking skills while attaining an academic edge, as well as for the opportunity to build my her research skills and direct her own research interests.

Kylie lives in the Perth suburb of Coolbellup, east of Fremantle, which she describes as one of Australia's best kept secrets - close to the coast and with a fabulous vibe!

Kylie enjoys travelling and would like to visit Namibia to see the rolling dunes, the gorgeous game, and the abandoned towns covered in sand. She believes finding yourself through travel is invaluable and is proud of her solo trips.

In the future, Kylie wants to work internationally, informing policy decisions regarding plant biosecurity or in the marriage of conservation and development goals. She would also love the chance to teach.

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Identification of effectors in *Venturia inaequalis*

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Venturia inaequalis is the causative agent of apple scab, a major pathogen of *Malus* spp. worldwide. This project aims to identify and characterise effectors in V. *inaequalis* and is supported by the Cooperative Research Centre for National Plant Biosecurity.

Effectors are pathogen proteins involved in infection. Effectors can also be recognised as foreign by plant receptors; recognition initiates a signal transduction cascade that results in plant resistance. Breaking of resistance can occur if either the plant receptor gene or the effector gene is deleted, or if the receptor is unable to recognise the effector due to a sequence mutation.

Effectors are therefore of interest for three reasons: for their direct role in infection, for their role in activating plant resistance, and for use in developing molecular tests that can differentiate between strains of *V. inaequalis* (including resistance-breaking strains) and other species of *Venturia*. Such tests would be of use in surveillance, particularly in Western Australia, which is currently free of *V. inaequalis* but requires ongoing surveillance to verify area freedom.

We are working with two putative effectors, with a focus on a fungal hydrophobin. Hydrophobin proteins are important for adhesion of the fungus to hydrophobic surfaces (e.g. apple leaves) and the ability to form aerial hyphae. This work is a continuation of work done at Plant and Food Research, New Zealand. We have isolates of *V. inaequalis* in which the hydrophobin gene has been silenced; we will be confirming the down-regulation of gene expression and examining the phenotype of these isolates. We will also attempt to characterise the gene in different races of *V. inaequalis*, and in the closely related species *V. pirina* (causative agent of pear scab) using PCR of genomic DNA.

We will also attempt to identify novel effectors by comparing the proteome of wild-type *V. inaequalis* to pathogenic variants and to *V. pirina*. Pathogenic variants could include races of *V. inaequalis*, or mutants that are known to have altered pathogenicity. The proteome of *V. inaequalis* can be separated into secreted, membrane-associated and cytosolic components. The secreted or membrane-associated proteome will be examined using Cy-dye labelled proteins run on two-dimensional protein gels (Differential In Gel Electrophoresis). We intend to characterise candidate effector genes and proteins, using mutant phenotyping, and immunochemical and molecular methods. Current results will be presented.

About the author:

Mr Daniel Jones is a Cooperative Research Centre for National Plant Biosecurity PhD candidate enrolled at the Department of Botany, La Trobe University. Most recently he was a biosecurity risk analyst at the Ministry of Agriculture and Forestry, New Zealand, assessing the biosecurity risk from import of Phaseolus spp. beans and table grapes. Daniel has worked in a range of fields at the University of Auckland; development of virus tests in ornamental plants, microbiology of wastewater, stream ecology, and apple flowering genetics. He gained a Masters in Science at the University of Auckland and Scion (Rotorua) working on genetic mapping in two species of Pinus.

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Feature extraction in hyperspectral imagery for emergency plant pest classification

Pattaraporn Khuwuthyakorn[1,2,3], Antonio Robles-Kelly[2,3,4] and Jun Zhou[2,3,4]

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Hyperspectral images are multi-dimensional data captured from and beyond the wavelengths of the visible light range. They contain much more spectral bands than the trichromatic and multispectral images. The pixel-level information in each band of the hyperspectral imagery exhibits specific spectral characteristics for the targets under study. This allows distinguishing types of materials which may appear as the same colour to the human eyes.

The traditional hyperspectral imaging application is in mining industries and geology for identifying materials and their compositions. As the hyperspectral sensors become cheaper and more practical, the access of this technology to public becomes more feasible. The application of the technology has expanded to broader range of areas, such as, ecology, agriculture and surveillance, etc. Hyperspectral imagery enables the employment of multi-dimensional spectral signatures to perform pest recognition. This hinges on the notion that different emergency plant pests have different characteristics, whose variation with respect to reflected light provides a unique description which can be used for detection and classification of pests into relatively narrow categories.

This paper introduces such a practice. We have developed a robust method for extracting texture features of insects, making use of high dimensional spectral-texture information. These hyperspectral signatures are used to generate a local image descriptor which is based upon Fourier analysis. Our descriptor contains a high information compaction property and can capture the space and wavelength correlation for the spectra in the pest images under study. This permits capturing the structural features of the plant pests of interest. Our preliminary results on an Oriental Fruit Moth image dataset are encouraging and show the utility of our method for plant pest recognition and classification.

About the author:

Ms Pattaraporn Khuwuthyakorn received her Bachelor of Engineering (Electrical Engineering) Degree in 1999 from Chiang Mai University, Thailand. She received the Master of Engineering Management Degree and also the Master of Engineering Science (Electrical Engineering) Degree from Queensland University of Technology (QUT) in 2005 and 2006 respectively. Patt is in the second year of her PhD studies with the Cooperative Research Centre for National Plant Biosecurity (CRCNPB). She is working on project CRC60075: NICTA Smart Trap, which is a joint project between the CRCNPB and NICTA. Patt's research interests are in the areas of Pattern Recognition, Computer Vision, and Spectral Imaging and especially in their applications. At present, Patt is studying at the Australian National University, Canberra, Australia, under the supervision of Dr Antonio Robles-Kelly, Dr Jun Zhou and Dr Louise Morin (CSIRO Entomology).

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Developing female fruit fly lures for improved market access

Katina Lindhout[1,2] and Scott Dalton[1]

[1]Industry & Investment New South Wales, [2]Cooperative Research Centre for National Plant Biosecurity

Fruit fly monitoring programs are critical to protecting Australian horticultural industries from exotic fruit fly incursions and for maintaining market access for producers within the Fruit Fly Exclusion Zone and other pest free areas of production. Traps containing lures specific to male fruit flies generally predominate in these programs due to the impracticality of existing female fruit fly lures. However, the supplementary use of female fruit fly lures in monitoring programs would greatly increase the chances of detecting an incursion, particularly of some exotic species where male flies are not responsive to lures.

The lure currently used for the detection of female fruit fly species consists of a liquid protein contained within a McPhail trap. This lure lasts less than a week in the field, becoming unattractive to fruit flies and unpleasant to service due to bacterial degradation and contamination. The development of a lure that is attractive to female fruit flies, yet easy to maintain would significantly increase the use of female fruit fly lures for surveillance purposes. The objective of the current research is to develop a new lure that is attractive to female fruit flies from a range of species, easy to maintain and effective under the varying climatic conditions experienced within Australia.

Two lures have been developed at NSW Department of Primary Industries' Gosford Primary Industries Institute (GPII). Both lures are protein-based and deployed in McPhail traps, however, one is formulated as a moist gel lure and the other as a liquid lure applied to vermiculite acting as an inert carrier. Based on literature reviews it was determined that the lures should comprise of a protein source, a sugar source, an ammonium compound and a binding agent. Using a wind tunnel, experimental lures were offered to protein-deprived female Queensland fruit flies (Bactrocera tryoni (Froggatt)) and the type and concentration of each component was optimised based on the number of flies attracted to the lure.

The second stage in the development of the lures was to determine their longevity and attractiveness when aged under different climatic conditions. To achieve this, lures were deployed within McPhail traps at four locations: Cairns (north Queensland), Alstonville (north coast NSW), Gosford (central coast NSW) and Wagga Wagga (south west slopes NSW) for twelve weeks at a time on two separate occasions in 2009 (February to April and May to July). Samples of the lures were collected and couriered to GPII every two weeks. To evaluate how attractive the lures remained during the twelve week period, the samples of lure were offered to protein-deprived female Queensland fruit flies in the wind tunnel as described previously. Neither of the experimental lures showed signs of microbial decay and remained attractive to female Queensland fruit flies throughout each of the twelve week trial periods.

The final stage of evaluation (commencing in September 2009) will involve setting trapping grids at each location and determining the effectiveness of the lures based on fly captures.

About the author:

Dr Katina Lindhout is a researcher with New South Wales Department of Primary Industries Market Access group based in Gosford. Katina specialised in market access entomology, her primary roles include the development of quarantine treatments for horticultural products and field experimentation of new fruit fly lures and baits.

Katina completed her Bachelor of Science (Honours) in plant pathology at the University of Queensland in 2001. She then went on to complete a PhD, researching the physiological basis of chilling injury in navel oranges with La Trobe University and CSIRO in 2007. Once completing her PhD Katina was employed by the NSW Department of Primary Industries, involved primarily in citrus and vegetable research. She has been in her current role as Market Access Entomologist since April 2008. Katina maintains collaborations with researchers in other state government departments and is an Honorary Associate of Macquarie University

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Policy and legal framework for a new development paradigm

Theofransus Litaay[1,2]

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It is widely acknowledge that the world has become 'smaller'; borders between nation states are no longer seen as separators but more as boundaries of different identities of groups who communicate with other. Direct communication between individual regions in different countries is frequent, even where communication between those same countries may be less frequent. Advancements in transport technologies have increased the movement of people and goods from one region to another. This movement brings along with it positive things such trading in/sharing goods, information and services, but also negative things such as viruses, pest and diseases.

The latter, of course, marks out the focus of this book's chapter, which is on the policy and legal frameworks which are potential facilitators of or impediments to national and international effective biosecurity, it is presently not understood what these are, who the originating bodies are, nor how policies at national, regional and local levels mesh (or not) to produce effective biosecurity management. This implies the effective management of biosecurity lies in the hands of many players; international, national and local. This chapter provides an introduction to existing policy and legal frameworks for biosecurity that presently (or should, might) impinge, and finishes by outlining some of the key issues that are suggested by these influences. The international framework starts with the discussion of Food and Agriculture Organization Biosecurity toolkit regarding policy and strategy making for integrated national biosecurity policymaking. Continuing with the *United Nations Convention on Biodiversity* which sets down some principles of engagement for policy sectors at all levels, while also providing guidelines for how they should work with local communities. These local communities and people, who in turn possess local knowledge, that has in many cases effectively managed biosecurity in these regions. The guiding question addressed in this paper is 'What are the prevailing international, national, and local policy and legal frameworks impacting on effective management of biosecurity?' Related to this question are the practical questions of what can be done to improve the effectiveness of biosecurity management using these frameworks. The findings, including the needs for improved local government capacity in dealing with international policy frameworks, suggest the need for a new development paradigm.

About the author:

Mr Theofransus Litaay's undergraduate and graduate degrees were in Law. He finished his master of laws degree at Vrije Universiteit, Amsterdam. He is a Lecturer of the Faculty of Law of Satya Wacana Christian University (SWCU) and researcher at the Centre of Eastern Indonesian Studies at the same university in Salatiga, Central Java. Since 2007, he took active part in the Australian-Indonesian Biosecurity Community Management Project (Ausindo-Biocom), a project of CRC National Plant Biosecurity conducted by Charles Darwin University and in Indonesia is supported by SWCU, Mahasaraswati University Denpasar, Nusa Cendana University Kupang, BaKTI (Eastern Indonesia Knowledge Exchange), JiKTI (Eastern Indonesian Researcher Network), Papua University Manokwari, etc. In September 2008, Theo started his PhD study as external student of Charles Darwin University, conducting research in greater Papua provinces. This research analyse the existing development paradigms and the possible development of a new 'development paradigm' that accounts for the effective engagement of all regulatory frameworks with local communities.

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Development of a cost effective web-accessible phosphine fumigation monitor for grain storage silos

Aaron Macdonald[1,2] and Les Zeller[1,2]

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A problem is evident in Australia's grain storage industry, in that there is no cost-effective and simple remote fumigation monitoring solution available. This results in resources being wasted to implement manual monitoring schemes, if they are implemented at all. The fumigation monitoring system we are developing will address this problem by utilising and developing cost-effective technologies and providing remote internet accessibility. We anticipate that this system will help to:

- encourage widespread adoption of effective remote monitoring
- reduce resource waste associated with manual monitoring
- improve compliance with fumigation standards
- improve control of pest resistance development
- improve grain quality assurance, and
- inform fumigation research.

A serious consideration of past and current trends in grain management and pest control clearly highlights the need for fumigation monitoring, which provides vital process feedback. Australia has rigorous grain quality standards, including nil tolerance of live insects. The development of resistance by pests to fumigants is a chronic problem, and is exacerbated by poor fumigation management. The process "must be conducted to a high standard to completely disinfest grain and slow or prevent resistance development" (Newman et al. 2003). In order to meet such standards, effective fumigation monitoring must be implemented wherever grain is fumigated. Our system is aimed to address this need.

About the author:

Aaron Macdonald is a recent graduate from the University of Southern Queensland – Bachelor of Mechatronic Engineering and Bachelor of Computer Science 2008 (Hons 1st Class). His research interest is in the application of computer and embedded systems to solve real-world problems. His final year engineering project involved using a combination of computer and embedded control to synchronise mechanical arms. He has worked on various projects, including systems for wireless irrigation telemetry, vehicle monitoring, timing cattle flight and making green speed measurements. He began working with Queensland Primary Industry and Fisheries early in the year on the conceptual stages of the phosphine fumigation monitor.

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Potato spindle tuber viroid (PSTVd) in Australia

Alison Mackie[1,2,3], Martin Barbetti[1,2,3], Roger Jones[1,2,3], Brendan Rodoni[1,4] and Simon McKirdy[1]

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Potato growing areas of Australia are currently considered free of *Potato spindle tuber viroid* (PSTVd) and this pathogen is classified as an emergency plant pest (Category 3) under the *Emergency Plant Pest Response Deed* (EPPRD). Since 2001 there have been six reported incursions of PSTVd in tomatoes in Australia. In each instance, an intense eradication program has successfully removed the source of inoculum. As a result of these successful eradication programs PSTVd is still considered a quarantine pest of significance here.

Six different pospiviroids infect solanaceous plants naturally and all are closely related to PSTVd. These related viroids have never been tested for in Australia and they could also be associated with PSTVd incursions of recent times. The presence of these different viroids could also confuse the diagnosis of PSTVd, particularly if these different viroids have high sequence homologies with PSTVd due tothe possibility of cross reactivity with PSTVd primers leading to mis-diagnoses.

Three strains of PSTVd have been detected in outbreaks of PSTVd in Australia over the last eight years. The 'Naaldwijk strain' was detected in tomatoes in 2001 and a survey of tomatoes in New South Wales detected a common European strain called PTVCGA. The last three outbreaks in Western Australia since 2004 have been of the 'Chittering strain' of PSTVd and their initial detection has always been in tomato plants. It is unclear at this point what the source of inoculum for these outbreaks was, by what pathway the pathogen reached tomato crops and what the impact of these PSTVd strains could be on tomato fruit yield and quality under Australian conditions.

Recent research in Europe has suggested that PSTVd infection may be widespread in certain wild solanaceous hosts, and that these infection reservoirs rather than seed transmissions in tomato may be responsible for outbreaks in tomato in different parts of the world. Recent research in Carnarvon, Western Australia, where the pathogen was detected in a host plant other than tomato and in non-solanaceous plants, has raised some interesting questions, particularly with respect to the original source of PSTVd inoculum.

The pathogenicity of the PSTVd strains detected, and any related pospiviroids that may be detected in future, on potatoes, and to a lesser extent on tomatoes, is not known. Critical aspects of the epidemiology of PSTVd in Australia are at best poorly understood, including how contact transmission occurs in tomato crops, the nature of temporal and spatial dynamics of epidemics in the field, the stability of PSTVd inoculum infectivity on different surfaces, and the role of nurseries in spreading the pathogen. A better understanding of these parameters will provide a sound basis for making decisions about appropriate containment and eradication strategies for this emergency plant pest.

About the author:

Ms Alison Mackie has been employed by the Department of Agriculture and Food, Western Australia (DAFWA) since 1999 and has worked on a number of projects in the plant pathology section, including culture collection, diagnostics, surveillance and horticulture pathology.

In Carnarvon Alison was involved in a number of projects including, Postharvest diseases of mangoes, Mango apical necrosis, PSTVd surveys and eradication programs and CRC30015 Hyperspectral plant pathogen detection.

Before moving to Carnarvon she had a variety of roles at DAFWA including, the Australian Quarantine Inspection Service (AQIS) plant pathologist for Western Australia, plant pathologist for exotic plant disease surveillance and Incursion Management, Post Entry Quarantine disease screening, Plant pathology input to the HortGuard and GrainGuard initiatives, and Maintenance of exotic plant pathogen diagnostic capabilities in Western Australia.

Alison was awarded a scholarship from Department of Agriculture Fisheries and Forestry in 2005 to study apple brown rot diseases at CSL in the UK.

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A stable and communicable classification of smut

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Smut fungi are mainly pathogens of grasses (Poaceae) and several affect economically-important crop species such as rice, sugarcane, sorghum and maize. Within the Ustilaginaceae are three genera, *Ustilago, Sporisorium* and *Macalpinomyces*. Morphological characters are inadequate in differentiating these genera, leading to putatively polyphyletic groupings, which complicate the taxonomy and identification of these organisms. The objectives of this research are twofold: to create a stable and communicable taxonomy of smut fungi and to complement this new systematic information with innovative means for identification through modern diagnostic technologies.

Phylogenetic reconstruction using molecular and morphological data will be used to deduce monophyletic groups within the smut fungi so that the genera and species can be reclassified into a stable, communicable taxonomy. Molecular data will be obtained from one mitochondrial locus (COX3), three nuclear housekeeping genes (GAPDH, EF1α and RPB2) and the ITS region. Morphological traits have been scored and analysed separately and in combination with sequence data to investigate character evolution and to help resolve phylogenies. Phylogenetic trees have enabled inferences in character evolution in the smut fungi and their diversification on Australian grass hosts. Phylogenetic hypotheses have been constructed using individual and concatenated data sets. Preliminary phylogenetic hypotheses from c. 50 taxa will be presented.

About the author:

Mr Alistair McTaggart is a PhD student supported by the Cooperative Research Centre for National Plant Biosecurity, enrolled at the Queensland University of Technology (QUT). He is investigating the systematics of a complex group of smut fungi using molecular and morphological methods. This research will have wide applications to facilitate in the detection and identification of smut fungi using molecular based platforms.

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The Fusarium oxysporum f.sp. *cubense* tropical race 4 vectoring ability of the banana weevil borer (*Cosmopolites sordidus*)

Rachel Meldrum[1,2,3], A.M. Daly[2] and Lucy Tran-Nguyen[2]

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Fusarium wilt of banana is regarded as one of the most widespread and destructive plant diseases in the recorded history of agriculture. Fusarium wilt is caused by the soil borne fungus *Fusarium oxysporum* f. sp. *cubense, Foc. Foc* is present throughout the world where bananas are grown. A particularly virulent strain capable of attacking Cavendish bananas in the tropics and referred to as tropical race 4 (*Foc TR4*), was discovered in 1997 in the Northern Territory. It has since led to the closure of several banana plantations.

To date, *Foc* TR4 does not occur in any other state of Australia. *Foc* TR4 is capable of killing plants faster than any other strain and disease can build up rapidly without control measures. There is no method for eradicating the fungus. Current control measures involve limiting the spread of the pathogen within and between farms. However, these measures have often been ineffective and disease has continued to appear in new areas. The reasons behind this spread have not always been easy to explain. The banana weevil borer, *Cosmopolites sordidus*, is present in most banana production areas throughout the world. It causes damage to banana plants by boring into the rhizome and pseudostem to feed and lay eggs. Weevils are capable of crawling between banana plantations. Therefore, it is important to know if they are capable of spreading *Foc* TR4. This project aims to determine the presence of *Foc* TR4 on or in banana weevils. This is highly important, especially if this pathogen is detected in areas of Australia or other countries where it currently is not present.

Revealing whether banana weevils are potential vectors of *Foc* TR4 will provide a greater understanding of disease epidemiology and could assist in limiting spread. While *Foc* TR4 was not successfully detected in the internal sections of the weevils, it was detected on the external sections. These preliminary results imply that *C. sordidus* can act as a carrier for *Foc* TR4 and possibly assist with its dispersal within and between plantations. *C. sordidus* may also vector other strains of *Foc* present in Australia and throughout the world.

About the author:

Ms Rachel Meldrum completed a Bachelor of Science degree (Biochemistry) at Charles Darwin University (CDU). She then achieved Honours at CDU researching the banana pathogen Fusarium oxysporum f. sp. cubense 'tropical' race 4 (Foc TR4). This is a plant pathogen which is not found elsewhere in Australia, only in the Northern Territory and is of great importance to one of Australia's most significant crops; bananas.

Rachel worked for the Northern Territory Department of Primary Industry, Fisheries and Mines (DPIFM) once she completed her undergraduate studies. She is now based with NT DPIFM and enrolled through the University of Queensland (UQ).

Rachel chose to study for a PhD through the Cooperative Research Centre for National Plant Biosecurity as it enables her to increase the knowledge about a plant pathogen that has an effect on Australia's biosecurity with possible international implications.

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Bacterial populations colonising fire blight susceptible host plants in Australia and their role in fire blight research

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Erwinia amylovora is a destructive pathogenic bacterium of plants in the family *Rosaceae* that causes the disease fire blight. In May, 1997, *E. amylovora* was reported in Royal Melbourne Botanical Gardens (RMBG). This discovery incited a rapid response to contain and eradicate the pathogen which, until then, had not been reported in Australia. The eradication program involved national surveys, sampling and diagnostics, host plant and vector destruction and the establishment of rigorous quarantine measures. Subsequent national surveys have failed to detect *E. amylovora* in Australia. However, these surveys have shown that some of the commonly used PCR protocols for detection of *E. amylovora* can generate false positive and/or confusing results with other bacteria living in the same ecological niche.

The presence of *E. amylovora* in the RMBG in 1997 is not in doubt, however, the size of the incursion and the results of subsequent studies have raised a number of interesting questions with regard to the bacterial populations present on hosts of *E. amylovora* in Australia. Firstly, what bacterial species are present on fire blight-susceptible hosts in Australia and what is the basis for the cross reaction with existing diagnostic PCR primers? This information could then be used in the design and validation of improved diagnostics for this organism. Secondly, what factors limited the spread and establishment of *E. amylovora* population reported in the RMBG? Victoria has conducive climatic conditions for fire blight disease establishment and there are known host plants and disease vectors present. Colonisation of flowers by *E. amylovora* is considered to be a crucial step in establishment of most natural fire blight infections. It is possible that other non-pathogenic bacterial species colonising flowers of fire blight hosts in Australia can out compete or behave antagonistically towards *E. amylovora*, thus preventing the establishment of fire blight?

During recent surveys of Rosaceous plants in Australia for *E. amylovora*, an array of bacterial species naturally colonising these plants were isolated. Sequencing of 16S rDNA showed that the saprophytic Australian bacteria were from a variety of genera including *Erwinia, Pantoea* and *Rahnella* and included the species *E. billingiae, E. tasmaniensis* and *Pantoea agglomerans*. Bacteria from these species have been implicated and tested as biological control agents against bacterial diseases of plants, including fire blight. We present further characterisation of the bacteria isolated from Australian surveys and explore their potential as antagonists of plant bacterial diseases.

About the author:

Ms Rachel Powney has a Bachelor of Science from the University of Melbourne and an Honours degree in Applied Science (Agriculture) from the University of Tasmania and now she's got her sights set on a PhD.

"Completing a PhD is a challenge and something I see as important for my career," says Rachel.

Since her honours graduation, she has worked as a plant pathologist with the Victorian Department of Primary Industries at its Knoxfield site. She is being supervised by Department of Primary Industries, Victoria Dr Brendan Rodoni and Dr Kim Plummer from La Trobe University.

Rachel chose to complete her PhD through the Cooperative Research Centre National Plant Biosecurity because as she says "It enables me to work on a really interesting project with a great team."

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Significance of spore release timing for predicting the spread of invasive fungal pathogens

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Seasonal and circadian patterns of spore release have been observed in a number of fungal plant pathogens that undergo aerial dispersal. Such patterns have been correlated with environmental conditions such as humidity, temperature and rainfall. It is therefore expected that individuals residing in different geographic locations will express different patterns of release.

Changes to the pattern of propagule release, resulting from changes in environmental conditions, are expected to alter the resulting dispersal event. Using a meso-scale, atmospheric model of aerial dispersal the significance of these changes are investigated.

Simulations performed in this study show that small changes in both the seasonal and circadian patterns of release can have significant effects on resulting aerial dispersal, leading to alternate dispersal events differing by thousands of hectares. The importance of this variation depends on the time scale in question and the need to quantify individual dispersal events. Any use of predictive modelling of aerial dispersal for management decisions will need to take into account a range of biological and environmental factors that can influence aerial dispersal. For organisms of importance to biosecurity and management agencies, studies need to be undertaken to fully understand pre-release processes such as release timing and the effect of these on aerial dispersal.

About the author:

Mr David Savage's undergraduate studies were undertaken at La Trobe University where he received a Bachelor of Mathematics. On completion of his degree he undertook a graduate program with the Department of Primary Industries, Victorian as a bioinformatics research scientist. He is currently completing his PhD with the support of the Cooperative Research Centre for National Plant Biosecurity. David's project involves modelling the aerial dispersal of fungal plant pathogens and investigating the possibility of detecting dispersal events before their distribution exceeds some critical point at which eradication becomes unfeasible.

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A Systematic Study of Australian Macropsine Leafhoppers

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Leafhoppers are phytophagous insects which can be serious economic plant pests, damaging plants through direct feeding and through their ability to vector plant diseases. In this project, the taxonomy and phylogeny of the Australian genera of Macropsinae (Insecta: Hemiptera: Cicadellidae) leafhoppers, are revised. Macropsines have received little taxonomic attention in Australia which, in part, reflects the taxonomic complexity of the group.

Macropsines have a worldwide distribution (over 550 species in 25 genera and subgenera), but have not been found on some Pacific Islands, nor South America. These leafhoppers feed on woody trees and shrubs. At least four macropsine species (in the genera *Macropsis* and *Oncopsis*) are known to transmit phytoplasma diseases overseas. This includes rubus stunt which affects blackberry, raspberry and other berry plants, peach yellows which affects peach, apricot and almond trees and alder yellows which can be transferred from alder trees to grapevines. These diseases and their vectors are not currently known to occur in Australia.

Macropsis and *Oncopsis* are the largest genera in the subfamily and have a predominantly Northern Hemisphere distribution but have also been used for a number of Australian species. Of the 46 species (in nine genera) of macropsines currently described from Australia, half have been tentatively placed within the holdall genus Macropsis.

The objectives of this study are to:

1. clarify whether *Macropsis* and/or *Oncopsis* occur in Australia
2. determine which macropsine genera are represented in Australia, and
3. determine the relationship between Australian and exotic species of macropsines, particularly pest groups known overseas.

This revision adopts a combined approach using traditional taxonomic methods to examine morphological characters and more recently developed molecular techniques to analyse DNA sequences of two genes (one mitochondrial and one nuclear gene region).

To date, the project has focused on morphological data and particularly on the most useful leafhopper characters derived from structures of the male genitalia. Over 1,000 specimens (types, identified non-types and undetermined material) held within collections around Australia and overseas, have been examined. A morphological character matrix capturing over 100 character states of around 500 specimens, will be used for phylogenetic analysis.

Based on preliminary sorting and morphological data, only two specimens match with *Macropsis.* However, one specimen is a female which cannot be identified reliably to genus using morphological features. The other specimen belongs to a subgenus, *Parapediopsis*, which doubtfully represents a true *Macropsis*. There is one new generic record for Australia and one new genus to be described.

Molecular DNA sequences of the mitochondrial COI gene region (550 - 650 bp) and a nuclear gene region (28S) are to be obtained. These data will help resolve problems with identifying females to genus and clarify generic boundaries.

Further analysis of morphological and molecular data will increase understanding of the taxonomy and systematics of existing Australian macropsine fauna and their relation to exotic pest species. This will contribute to improving Australia's diagnostic capability to identify emergency plant pests.

About the author:

Ms Linda Semeraro's main interest is in the taxonomy and systematics of leafhoppers (Cicadellidae) She has been working in the Victorian Agricultural Insect Collections for over nine years (both full-time and part-time). Her role has involved identification of insect specimens and curation of the collections. Linda completed a Bachelor of Science at Macquarie University (New South Wales), graduating in 1995. After completing her degree Linda worked as a volunteer at the Australian Museum Mammalogy Collection, assisting with curatorial tasks. She was also involved with a project which focussed on the diet of Wedge-tailed Eagles particularly in the Mutawintji (previously known as Mootwingee) National Park, near Broken Hill.

Linda was employed by New South Wales Department of Primary Industries (Rydalmere) for a few years as a scientific illustrator in the insect collection Agricultural Scientific Collections Unit (ASCU). The ASCU later moved to Orange, New South Wales in 1997 where she worked with Dr Murray Fletcher (Australia's leafhopper specialist) for more than two years, illustrating and photographing leafhoppers of economic significance. In 2000 Linda moved to Melbourne to work with Department of Primary Industries, Victoria in the Victorian Agricultural Insect Collection, where she is still currently based. In her current position she has had the opportunity to broaden my knowledge and taxonomic skills and develop a better understanding of insect biosecurity issues in Australia.

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Individual-based modelling of the evolution and spread of resistance to pesticides in stored grain insect pests

Mingren Shi[1,3], Rob Emery[2,3] and Michael Renton[1,3,4]

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Evolution of resistance to pesticides is widely recognised as a serious issue for the long-term sustainability of Australian agricultural systems. This is particularly critical when the pest management strategy is reliant on a single pesticide (phosphine), as is the case for the lesser grain borer. This study will develop individual-based models that incorporate processes such as organism life cycle and biology, effects of environment, genetics, sampling, effects of management, and spatial spread within and between storage facilities. The aim is to help predict population dynamics, the evolution of resistance, and the spread of individuals and resistance genes under different management scenarios and thus identify effective long-term strategies for monitoring and managing resistance.

We will present the structure and assumptions of a prototype version of the model, explaining how each beetle is represented separately. The way that environmental and management effects are simulated will be explained, as will the approach used to model genetics and resistance. Some preliminary results will be shown.

About the author:

Dr Mingren Shi received his first PhD degree in Applied Mathematics from Murdoch University in 1997. He has worked as a Postdoc at University of Western Australia (UNSW), as a Research Fellow at UNSW, and a lecturer in Statistics/ Operations Research at University of Southern Queensland. He has also worked as a (casual) Coordinate Lecturer and Teaching Assistant at the University of Western Australia where he was lecturing and tutoring in Industrial Statistics and Total Quality Management, Engineering Mathematics in 2008.

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The suppression and transmission of *Phytophthora* disease is assisted by fungicide application to plants

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Some *Phytophthora* species are known to be among the most devastating plant pathogens worldwide, infecting a wide range of ornamental, agricultural and native plants. In the United States of America, *P. ramorum* has wreaked havoc on natural and ornamental landscapes and *P. kernoviae* is another pathogen of serious concern in the United Kingdom and New Zealand. It is thought that international and interstate plant trade is one of the main pathways for spread of these pathogens.

Sampling and testing for plants for the presence of disease is a labour-intensive and costly process. For most plants under inspection, health is assessed by observation of visible symptoms of disease. Recent research from nursery surveys and controlled experiments has shown that viable *Phytophthora* propagules can be recovered from asymptomatic plant tissue. This may be due to the use of fungicides, which suppress rather than kill the pathogen. As time passes, fungicide residues dissipate and the pathogens can resume their life cycles, spread and cause disease outbreaks.

Two controlled glasshouse experiments are in progress to test the suppression of *Phytophthora* disease by fungicide treatments, and the rate at which disease resumes in new non-fungicide treated host plants, when placed in contact with fungicide-treated plants. In the first experiment, plants infected with *Phytophthora cinnamomi* and subsequently treated with one of three fungicides at a manufacturer's recommended rates, will be harvested periodically over two years, with inspection for disease symptoms and recovery of the pathogen. In the second experiment, root material from all plants from each harvest used in the first experiment is buried in pots of healthy non-fungicide treated plants. These plants will be monitored for disease expression, to determine the rate of transmission of the pathogen from fungicide-treated plant material. Implications of results from these experiments will be discussed

About the author:

Ms Amy Smith is a second-year international postgraduate student at Murdoch University. She received a Bachelor of Science degree from the University of California, Davis in Microbiology in 1999, and spent several years managing a large, active Forest Pathology and Mycology laboratory at the University of California, Berkeley. She is currently studying the potential spread of disease by plant production nurseries in Western Australia. Amy's project will utilize molecular, traditional plant pathology, and modelling techniques to study the epidemiology of Phytophthora cinnamomi as it moves from the nursery environment into native and urban garden landscapes. She hopes her project will bring conservation and biosecurity awareness to the garden industry, government and public, in regards to their use and handling of plants and soil.

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Integrated eradication of pest insects

Rajendra Soopaya[1,2,3], Bill Woods[1,2], Lloyd Stringer[1], David Williams[1,4], Max Suckling[1], Greg Baker[1]

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Sterile insect technique (SIT), use of pheromones and bio pesticides represent the cornerstones technologies of future integrated pest eradication practice. SIT is environmentally benign and suitable for area wide use. Pheromone-based programs have the key benefit to be highly selective thus have few non target impacts and have multiples uses in the form of mass trapping, attract and kill or mating disruption.

Stage one of our CRC project reviewed the technologies currently available for pest eradication in four insect orders: Lepidoptera (moths and butteflies), Coleoptera (beetles), Diptera (flies) and Hemiptera (sucking bugs). SIT studies in Western Australia and New Zealand using light brown apple moth (LBAM), *Epiphyas postvittana* have identified irradiation doses that can either induced full sterility in pupae or increase mortality and sterility in the F_1 generation. LBAM was chosen as a model species because it is representative of a wide range of pestiferous Tortricids worldwide, as well as being present in both countries. Stage 2 of the project will investigate the effective use of pheromones in mating disruption especially in urban and peri urban areas. The novel technique known as mobile mating disruption (MMD) whereby sterile mediterranean fruit flies were used as a carrier of moth pheromones to disrupt mating of moths has shown promising results in preliminary trials in suburban Perth. More trials on mobile mating disruption are planned for this spring as well as the use of biodegradable carriers to apply pheromone in vineyard areas in South Australia. Finally an integrated approach using pheromones, SIT and biological insecticides will be trialled in urban, peri urban and orchard areas.

About the author:

Rajendra Soopaya completed a Bachelor in Crop Science in 1994. From 1988 to 2006 he worked as a Research Scientist in the Plant Physiology Department of the Mauritius Sugar Industry Research Institute. From 1997 to 1998, he completed a master degree in Crop Physiology at the University of Reading in the United Kingdom. Rajendra migrated to Australia in 2006 and took employment as a Research Assistant at the University of Western Australia before joining the Department of Food and Agriculture of Western Australia in 2007 as a technical officer. Rajendra is presently working on Sterile Insect Technique for Mediterranean fruit flies and also on developing integrated eradication strategies for emergency plant pests using Light brown apple moth as a model species.

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Eradication of *Elsinoe ampelina* by burning infected grapevine material

Mark Sosnowski[1,2], Robert Emmett[3], T.A. Vu Thanh[4], Trevor Wicks[1] and Eileen Scott[4]

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Burning infected plant material is widely used in the control and eradication of endemic and exotic pathogens. However, there is little scientific evidence to confirm that pathogens are eliminated during this process. We report experiments to assess the efficacy of burning as a means of eradicating pathogens from woody plants.

Black spot (anthracnose), caused by *Elsinoe ampelina*, is an important disease of grapevines worldwide. The fungus infects leaves, stems, petioles and berries. This pathogen was chosen as a model to develop an eradication strategy for the exotic disease black rot, caused by *Guignardia bidwellii*. Black rot has similar biology and epidemiology to black spot and could have a severe economic impact on the wine industry if it became endemic.

An experiment was conducted in the Sunraysia district of Victoria. Grapevines were inoculated in spring 2007 and drastically pruned in July 2008 in an experiment to eradicate the disease. On treated vines, all plant material above the crown was removed and placed in a pit (5 x 3.5 x 0.5 m). In August 2008, six steel poles were placed upright at random within the pit. Steel mesh bags, containing infected vine canes and temperature crayons (Tempilstik) in glass Petri dishes were attached to the poles at 20 and 50 centimetres above the pit floor. Another set of mesh bags was buried five centimetres below the surface of the pit floor. After the vine material was burnt, the mesh bags were collected and the ash was transferred to plastic tubes. Unburnt canes from untreated control material and buried samples were grated. All samples were stored at 3-4ºC.

A bioassay was conducted in a glasshouse at 22-28ºC in December 2008 using potted grapevines. The three youngest expanded leaves on each shoot were sprayed with deionised water and dusted with the ash or grated vine material. Each treatment was applied to three to four shoots per vine and replicated twice. The inoculated shoots were covered with polyethylene bags for 48 hours to promote spore release, after which bags were removed and leaves sprayed again with deionized water to spread spores. Bags were replaced and left overnight to promote germination.

Twelve days after inoculation, the vines were assessed for symptoms of black spot. No leaf symptoms developed on plants inoculated with ash whereas significant symptoms were observed on plants inoculated with grated material from the controls and less severe symptoms occurred on plants inoculated with buried cane material. The temperature crayons indicated that the fire reached in excess of 250°C and variable temperatures up to 60°C occurred five centimetres below the soil surface.

These results confirm the efficacy of burning infected vine material, as temperatures exceeded those that are lethal to the fungus and the bioassay verified that this was the case. However, any pathogen on debris which penetrates the soil may not be eliminated. Further research is underway to evaluate burning for eradication of the bacterium *Xanthomonas translucens* from pistachio trees.

About the author:

Mark Sosnowski is a Research Scientist with South Australian Research and Development Institution (SARDI). After graduating with a Bachelor of Agricultural Science degree from the University of Adelaide, he commenced working for SARDI in 1997 and went on to complete a PhD in 2002, studying the epidemiology and management of blackleg disease of canola at the Uni of Adelaide.

Since 2003, Dr Sosnowski has been responsible for research on managing eutypa dieback disease in grapevines at SARDI as part of the Cooperative Research Centre for National Plant Biosecurity (CRCNPB) for Viticulture and remains responsible for supervision of current Grape and Wine Research Development Corporation (GWRDC) supported research of eutypa dieback. Currently managing a national CRCNPB project aiming to optimise eradication strategies for exotic plant pathogen incursions on perennial crops, Mark is concentrating his own research on the eradication of grapevine pathogens.

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Native parasitic wasps (Hymenoptera: Braconidae): A new tool for fruit fly (Diptera: Tephritidae) incursion management in Australia?

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Inundative releases of Australian parasitoid species have resulted in improved management of fruit flies (Tephritidae) in several regions of the world including incursion management programs incorporating the sterile insect technique (SIT). Despite this, and the importance of the Queensland fruit fly (Qfly), *Bactrocera tryoni* (Froggatt) as an emergency plant pest, inundative releases of parasitoids are not yet used for the management of Qfly in Australia. A number of hymenopteran parasitoids are known to target Qfly in Australia and these parasitoids are used successfully overseas to control several fruit fly species exotic to eastern Australia.

The Australian native larval parasitoids *Diachasmimorpha kraussii* (Fullaway) and *D. tryoni* (Cameron) are both used for the control of the Mediterranean fruit fly ('Medfly'), *Ceratitis capitata* (Wiedemann), which is present in Western Australia and may be used for the management of this potential exotic incursion into the southern and eastern states of Australia. The introduced egg parasitoid Fopius arisanus (Sonan) parasitises Medfly, the Melon fruit fly, *Bactrocera cucurbitae Coquillett*, the Oriental fruit fly, *B. dorsalis* (Hendel) and may be useful against incursions of these fruit fly pests. This paper will present results of field surveys of the fruit fly parasitoid fauna of inland New South Wales (NSW) and the subsequent development of rearing protocols for one of these species. Findings will be presented on two species of parasitoids detected for the first time in inland NSW. Results will be discussed in relation to how these studies may contribute towards the successful inundative release of parasitoids for the control of fruit fly in a biosecurity context.

About the author:

Jennifer is a second year PhD student with the Cooperative Research Centre for National Plant Biosecurity based at the E.H. Graham Centre for Agricultural Innovation (Charles Sturt University and New South Wales Department of Primary Industries), Wagga Wagga. Jennifer has an interest in both biosecurity and biological control. Jennifer completed her Bachelor of Science in Agriculture (Hon 1) at the University of Sydney in 2007 and worked in the Operational Science Program (Entomology) at the Australian Quarantine and Inspection Service, Sydney prior to commencing her postgraduate studies.

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Bilingual glossary as strategy for bridging cross-cultural knowledge of global biosecurity

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This paper outlines the development of a social science and science glossary in the management of biosecurity in northern Australia and eastern Indonesia. Specific issues related to bilingual, bicultural communication and the growth of research capacity in the field of biosecurity are addressed. For the last three years, the Australian Cooperative Research Centre for National Plant Biosecurity has conducted a cross border project, namely 'Australian-Indonesian Biosecurity Management' based on a partnership, collaboration, and cooperation between various institutions, both in Australia and Indonesia.

It was soon apparent that knowledge about the biosecurity issues of communities on both sides of the border is very limited. For this reason, we have developed a unique glossary of terms called *'Glossary of Biosecurity Management'.* This glossary, for the first time, documents and defines terms across disciplines necessary to understanding community management of biosecurity (CMB). The three main areas are biosecurity, social science and community, and are presented in both English and Bahasa Indonesia languages. It is arranged in four sections:

1. identifying that the purpose of glossary is to increase clarity and consistency in the use and understanding of terms and definitions around CMB, as well as for information and knowledge exchange
2. building an initial list of terms and definitions using a semiautomatic glossary acquisition, with source mainly coming from the research teams' reports, input from an extensive international network of academic and practitioner colleagues and internet access
3. evaluating the glossary by team members and the international networks mentioned above, and
4. revising and printing the first edition.

The glossary will be continuously revised. It is also planned to develop the bilingual glossary into a 'multilingual glossary of CMB', using other major languages in the world. Of key importance will be the capacity of the glossary to bridge the cross-cultural knowledge bases of global biosecurity and to provide a tool for promoting cross-cultural communication and common understandings in this area.

About the author:

For over a decade, Professor Sang Putu Kaler Surata has been implementing agricultural and NRM research outcomes to make a positive difference in rural communities.

His research and application strategies show that achieving change in communities relies on, Harnessing community capacity (via his community development model), and a whole-of life education through teacher training programs which educate adult teachers-to-be while influencing leaders of the future.

In recent years he has focused his research on his finding that multi- and cross-disciplinary research is essential to achieving sustainable uptake of research outcomes in both agriculture and NRM settings. In undertaking this research he has contributed strongly to international research partnerships in the United States of America and Australia.

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Economic analysis of two diagnostic protocols

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Tilletia indica, the cause of Karnal bunt of wheat, is the target of strict quarantine regulations by most wheat growing countries and its presence raises trade barriers to wheat exports. The international diagnostic protocol currently used in Australia involves the tentative identification of the spores based on morphology followed by germination of the spores and a molecular protocol to confirm the identity. An enhanced protocol has been developed in which the detection for suspect samples based on morphological criteria is substituted by a highly sensitive molecular assay with a detection limit of <5 spores for a 50g grain sample. The development of a technique using a single spore sandwich to release DNA directly for molecular diagnosis has enabled the germination step required for pathogen confirmation to be bypassed. Confirmation in the enhanced protocol involved both morphological and molecular diagnosis to ensure a near zero risk of a false positive that may be associated with a highly sensitive molecular technique. An economic analysis has been performed to compare the economic costs of the current and the enhanced protocol and their relative performance in different scenarios. The results indicated that the current protocol would be more economical in the monitoring and identification of *T. indica* in current infested areas. However, the enhanced protocol is significantly more economical and sensitive to be used in an exotic pest incursion scenario or a survey to demonstrate area of freedom. The enhanced protocol also reduces the elapsed time before a definitive identification can be achieved.

About the author:

Dr Mui-Keng Tan was appointed to the position of a Senior Research Scientist in 2002 at New South Wales Department of Primary Industries. She played a central investigator's role in various industry supported projects on the detection of herbicide resistance in agricultural weeds and in the molecular marker development for quality traits in wheat. Her research has provided valuable commercial or industry outcomes besides having contributed new knowledge to basic science.

Mui-Keng is currently the Cooperative Research Centre for National Plant Biosecurity project leader for developing the national diagnostic protocol for Karnal bunt, a quarantine pathogen for wheat.

Her research interests includes, marker development for wheat quality traits and the genetic and molecular basis of agronomic traits (quality, stress, disease resistance) in cereals, fungal systematics and development of diagnostic molecular protocols for plant pathogens and molecular basis of herbicide resistance in wild radish, wild oats and ryegrass.

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Mathematical modelling of fumigant resistance affected by refuges

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Grain borer beetles are a pest in that they spoil grain food for human consumption. The beetle tends to reach unnaturally high population numbers when they find the mass storage of grain food (grain silos). Stored grain infestations are controlled with the application of phosphine fumigant pesticide. Genetic resistance to phosphine has evolved in the insects, and the emergence of large proportions of the resistant genotype is a major threat to the grain industry. There is a need to predict the outcome of particular pesticide application strategies. The outcome of interest is to identify inadequate pesticide application leaving high proportions of resistant genotypes to breed. This project aims to develop and implement mathematical models to simulate the effect of the application strategies when certain environmental factors are input, and visualise data relating to resulting eradication success and emergence of resistance.

About the author:

Mr Jason Thorne has been a Lecturer at Charles Sturt University for three years. He was Manager of the Sydney University IT unit for 10 years before becoming the Director. Jason is interested in rugby union, water polo, soccer, guitar and piano.

Jason is currently completing his PhD with the Cooperative Research Centre for National Plant Biosecurity. His project is CRC60129: Mathematical modelling of fumigant resistance affected by refuges.

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Characterisation and multiplexed detection of endemic and exotic begomovirus species in Australia

Sharon Van Brunschot[1], Paul Campbell[2], Julianne Henderson[3], Denis Persley[2], John Thomas[2], Bronwy Battersby[4], Andre Drenth[3], Andrew Geering[1,2]

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Begomoviruses (family *Geminiviridae*) cause economically important diseases on many dicotyledenous crop plants worldwide. Epidemics of begomoviruses are increasing in frequency due to the capacity of these viruses to rapidly evolve, the globalisation of trade, and the worldwide dispersal and polyphagous nature of the efficient whitefly vector *Bemisia tabaci* (B biotype).

In 2006, the exotic begomovirus Tomato yellow *leaf curl virus* (TYLCV) was detected for the first time in Australia in commercial tomato plantings surrounding Brisbane, the Lockyer Valley and Bundaberg (Queensland). The introduction of TYLCV has had a significant economical impact on tomato production, with disease incidence in some areas reaching 100%.

To investigate the identity of the introduced strains, the complete genomes of eight TYLCV isolates were sequenced. Phylogenetic analysis revealed two closely related (99% mean nucleotide diversity), but geographically segregated, clades. Clade A (Brisbane/ Lockyer Valley) was more closely related to TYLCV from California, than to Clade B (Bundaberg). Clade B was more closely related to TYLCV from China and Japan, than to Clade A. Several defective DNA components were detected from one TYLCV isolate from Brisbane, and characterised. These results suggest either two separate introductions of TYLCV into Australia, or alternatively a founder effect where a rare genetic variant in one region was introduced to a second region and became the predominant strain.

To limit further spread of TYLCV in Australia and to detect further incursions of exotic begomovirus species, rapid, efficient and reliable diagnostic strategies are required. Multiplexed real-time PCR diagnostic assays for the detection of endemic and exotic begomoviruses are being developed to improve the efficiency and accuracy of routine detection strategies. The overall aim of this research is to transfer the DNA probes to a nanosensor platform (OptoPlex™ beads), to enable the simultaneous detection of a virtually unlimited number of begomovirus species and strains.

About the author:

Sharon has been a PhD student with the Cooperative Research Centre for National Plant Biosecurity (CRCNPB) since October 2007. She chose a project aligned with the CRCNPB as she has a keen interest in biosecurity, particularly in technology development for improving diagnostic capacities.

Sharon has been working in plant pathology since 2001 as a student and researcher with the Cooperative Research Centre for Tropical Plant Protection, Queensland Department of Primary Industries and Fisheries, and The University of Queensland. She has worked on various projects researching and developing diagnostic tests for fungal pathogens of bananas (Fusarium oxysporum f.sp. cubense, Mycosphaerella sp.), cotton (Fusarium oxysporum f.sp. vasinfectum) and citrus (Guignardia citricarpa).

Most recently, Sharon worked with Dr Elizabeth Aitken (Senior Lecturer, University Queensland) to develop a new postgraduate course focussing on molecular diagnostics for plant protection.

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Development of a multiplexed immunoassay for the detection of banana viruses

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Banana is a very important staple food and export commodity in tropical regions of the world. Pathogens, including at least 20 different virus species, are major limiting factors to production. The primary means of control of these viruses is through the provision of clean planting material to farmers, for which good diagnostic methods are needed. Significant advantages could be achieved if all viruses could be detected simultaneously. The most feasible method for a multiplex assay is use of an antibody array as the banana streak viruses are endogenous pararetroviruses and nucleic acid assays are incapable of distinguishing integrated from actively replicating viral DNA. The objective of this project is to produce a diagnostic assay of this type.

For the antibody array, we plan to use the OptoPlex™ nanosensors, which are optically-encoded, silica nanobeads that are analysed in a high throughput flow cytometer. Single chain variable fragments (scFvs) will be attached to these nanosensors and the virus detected in a sandwich assay using a fluorophore-labelled scFv.

Production of scFvs to each of the viruses is at different stages. A scFv to *Banana bunchy top virus* has been cloned from a mouse hybridoma cell culture. The coat protein of Abaca bunchy top virus has been expressed in *vitro* and will be used to immunise a chicken for development of an enriched scFv library for biopanning. The coat proteins of the badnaviruses causing banana streak disease are produced through the action of an aspartic protease on a polyprotein precursor and the boundaries of the coat protein have not yet been defined. We have purified *Banana streak Mys virus* and identified the putative coat protein. Protein samples are currently being analysed by MALDI-TOF/TOF to determine the amino acid sequence. Once characterised, these proteins will also be expressed *in vitro* in order to develop scFvs.

About the author:

Ms Jenny Vo's interest is to develop new detection methods for detection of banana viruses. She is also interested in recombinant immunological reagents for detecting plant pathogens and the application of nanotechnology in plant pathogen diagnostics.

In 2007 Jenny completed a Bachelor of Biotechnology graduating with First Class Honours (major in Microbial Biotech) at the University of Queensland. Her Honours research project was conducted with the Cooperative Research Centre for Sugar Industry Innovation through Biotechnology. As part of her Honours Jenny was involved in a major project to develop an E.coli strain for production of commodity chemicals utilising sugarcane as the sole carbon source. The Honours project also included the study of all steps involved in commercial development for a biotechnology product such as research and development, marketing, intellectual properties protection, regulatory issues, production and economic analysis.

Jenny is currently completing her PhD with the Cooperative Research Centre for National Plant Biosecurity. Her project is CRC60107: Nano Bananas. Jenny is enrolled through the University of Queensland at the School of Australian Institute of Bioengineering and Nanotechnology. Her research is based at Queensland Primary Industries and Fisheries.

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Development of a biosecurity training program for the stored grains industry

Paul Weston[1,2] and John Kent[1,2]

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With recent changes to the international trading scheme for grains in Australia, and concomitant increase of grains stored on-farm and in bulk-handling facilities around the country, the need for a work force properly trained in maintaining quality of stored grain is greater than ever. In addition, the worrisome appearance of populations of stored-grain insect pests exhibiting very high levels of resistance to phosphine further emphasises the need for such training. In response to these needs, a training program is being developed, aimed at providing the educational tools needed by managers of stored grains, whether on-farm or in bulk handling facilities, to enable them to maintain grain at the highest quality level and to recognise the appearance of phosphine-resistant pests or exotic pests of national concern.

The training program is being developed with strong involvement of industry to ensure that needs of end-users are met. Following consultation with industry members, extension educators, and members of the Australian plant biosecurity community, it was decided to organise the training program in two tracks, one focused on managers of bulk-handling facilities and extension educators (the 'bulk handler track'), and the other focused on grain producers. The focus of the current training program is the bulk handler track; those receiving training via this track would then be responsible for delivering course content to producers using resources provided via the training program as well as those developed by themselves.

Based on prior experience with delivery of similar course content, and utilising input from industry consultants, it was decided to structure the course as a combination of home study and a hands-on workshop. The home study portion will be delivered electronically; those having broad-band internet connections will be able to access the content via the internet, while those with limited internet access will be able to explore the course content via CD-ROM. The hands-on workshop will allow course participants to view stored-product insects directly, to view and participate in demonstrations of grain sampling and fumigation techniques, and to receive first-hand exposure to other techniques and information that is difficult to communicate via electronic media.

Charles Sturt University, with its experience in distance education and providing similar course content, will be the registered training organisation responsible for delivering course content and course administration. Course assessment will be competency based, using competencies endorsed in the Agriculture, Horticulture, and Conservation and Land Management training package.

Given the broad applicability of risk management to worker safety, grain biosecurity, and basic business operation, risk management has been selected as an overarching theme of the course. By providing background information on risk management and illustrating its applicability to these key areas of the stored-grain industry, it is hoped that participants completing the training program will be better equipped to maintain Australia's position in world grain markets and to detect new threats to grain biosecurity.

About the author:

Dr Paul Weston is employed as a Support Academic Research Officer and Adjunct Senior Lecturer at Charles Sturt University in Wagga Wagga, New South Wales. He obtained a Bachelor degree in Biology from Cornell University in 1979, followed by an Masters degree in Electrical Engineering and Systems Science from Michigan State University in 1981. Feeling the need to get back to his biological roots, Paul obtained a PhD in Entomology from Michigan State University in 1986, conducting research on reproductive biology and behaviour of two dipteran pests of vegetables and simulation modelling of insect movement behaviour. After completing his graduate degrees, he worked as a post-doc at the University of Kentucky, where he studied behavioural responses of mites to semiochemicals produced by tomato plants. Following that, Paul was hired by Kentucky State University to develop a research program focused on insect pests of stored grains. Momentarily completing the circle, he took a faculty position at Cornell University in 1998, where he developed a research, extension, and teaching position dealing with arthropod pests of trees and shrubs. Most recently, he and his wife relocated to Australia (in 2008), where he was hired by Charles Sturt University to head up a training project for managers of stored-grain facilities. He also lectures in entomology and pest management at Charles Sturt University, and advises students conducting research in analytical organic chemistry.

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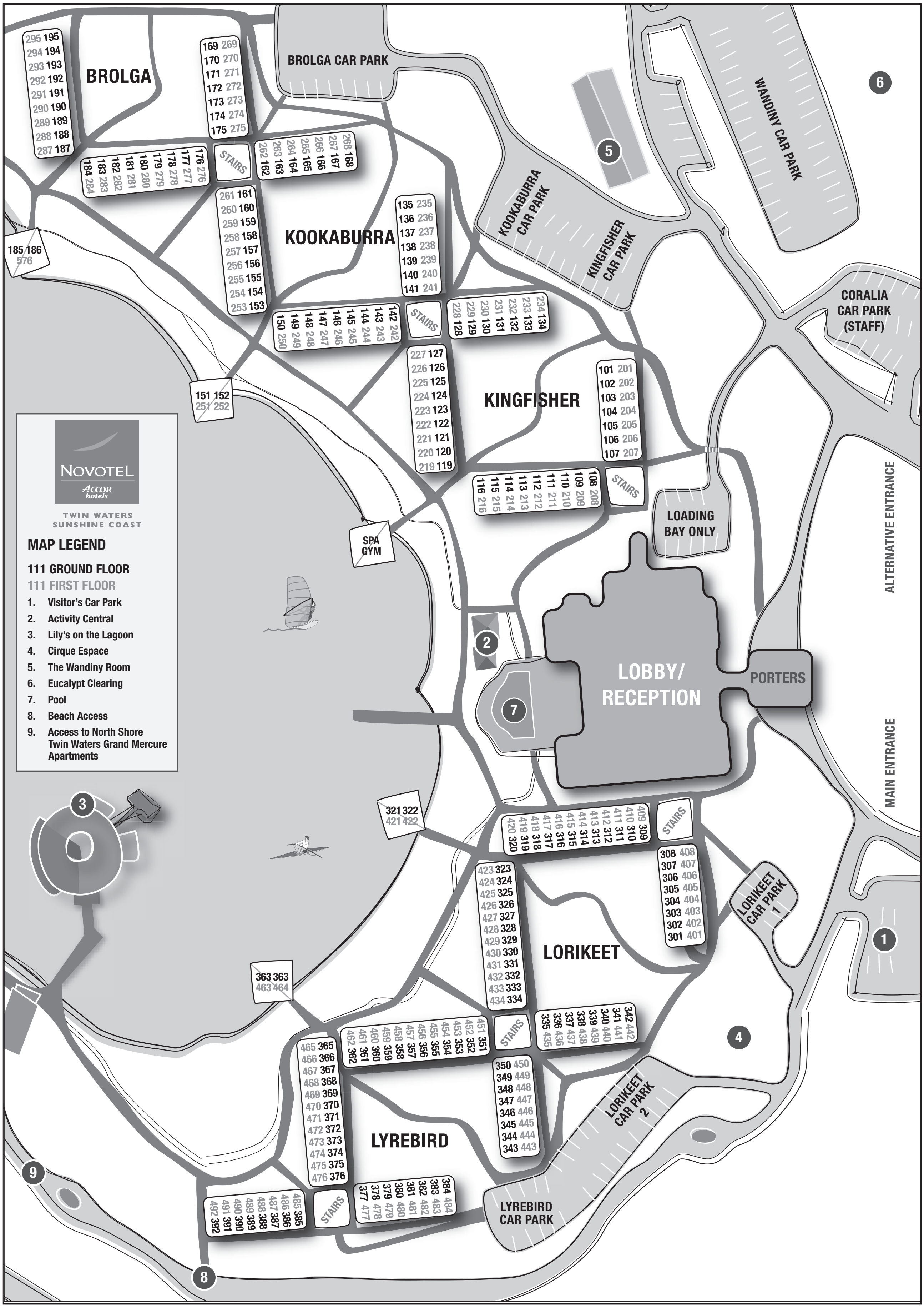
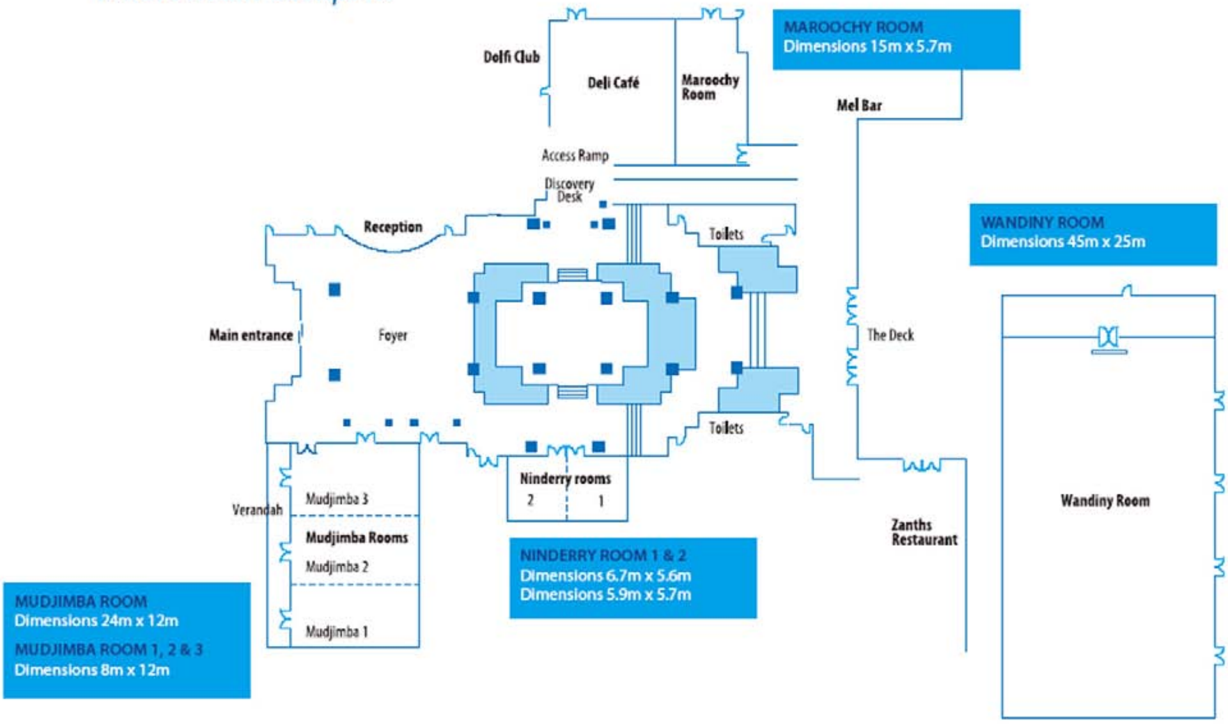
Resort map


BROLGA
BROLGA CAR PARK
KOOKABURRA
KOOKABURRA CAR PARK
KINGFISHER CAR PARK
WANDINY CAR PARK
CORALIA CAR PARK (STAFF)
KINGFISHER
LOADING BAY ONLY
ALTERNATIVE ENTRANCE
SPA GYM
LOBBY/ RECEPTION
PORTERS
MAIN ENTRANCE
LORIKEET
LORIKEET CAR PARK 1
LORIKEET CAR PARK 2
LYREBIRD
LYREBIRD CAR PARK
STAIRS
NOVOTEL
ACCOR hotels
TWIN WATERS SUNSHINE COAST
MAP LEGEND
111 GROUND FLOOR
111 FIRST FLOOR
1. Visitor's Car Park
2. Activity Central
3. Lily's on the Lagoon
4. Cirque Espace
5. The Wandiny Room
6. Eucalypt Clearing
7. Pool
8. Beach Access
9. Access to North Shore Twin Waters Grand Mercure Apartments

resort main complex



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