THE UNIVERSITY of ADELAIDE

Annual Report 2014

Waite Research Institute

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seek LIGHT

The Peter Waite Legacy and Vision

Peter Waite was a visionary. The son of a Scottish farmer, he immigrated to Australia in 1859 and prospered in the fledging colony of South Australia. Throughout his journey from the pastoral lands of the mid-north of South Australia to the boardroom of the "General and Commission Agent Company", later to become Elders Smith & Co Ltd, Peter Waite embraced and developed innovative and contemporary farming practices.

Peter Waite gifted his homestead, Urrbrae House, and the surrounding property of 299 acres (121 ha) to The University of Adelaide in 1923 for education and research purposes. The Waite Agricultural Research Institute commenced operations on the site in 1924.

In explaining his gift, Peter Waite wrote:

"I have been much influenced by the wonderful work our agriculturalists and pastoralists have accomplished hitherto in the face of the very great odds they have had to meet. With comparatively little scientific training they have placed our wheat, wool and fruit in the highest estimation of the world: our sheep have been bought to such perfection that they are sought after not only by all our sister states, but South Africa. Our agriculture machinery has been found good enough even for Americans to copy; and our farming methods have been accepted by other states as the most up-to date and practical for Australian conditions. We have now reached a point when it behoves us to call science to our aid to a greater extent than hitherto has been done, otherwise we cannot hope to keep in the forefront."

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The 'Waite' at a glance

The Waite is Australia's most recognised and respected agricultural research and teaching brand

The Waite Campus is the largest agricultural research and teaching precinct in the Southern Hemisphere. Located in the south-eastern suburbs of Adelaide, South Australia, the Campus hosts:

- The University of Adelaide's School of Agriculture, Food and Wine
- CSIRO (parts of the Agriculture and Land & Water flagships)
- South Australian Research and Development Institute (SARDI)
- Australian Wine Research Institute (AWRI)
- Australian Genome Research Facility (AGRF)
- Australian Grain Technologies Pty Ltd (AGT)
- Arris Pty Ltd
- Urrbrae House historical precinct
- Food SA

In addition, the Waite hosts the following specialist research centres of national significance:

- Australian Centre for Plant Functional Genomics (ACPFG)
- Australian Plant Phenomics Facility (The Plant Accelerator)
- ARC Centre of Excellence in Plant Cell Walls
- ARC Centre of Excellence in Plant Energy Biology (node)
- FOODplus Research Centre
- Wine Innovation Cluster (WIC)

Over the last 90 years, the Waite Campus has developed through the pursuit of excellence in agricultural science and through collaboration between the collocated organisations to become:

- Australia's most recognised and respected agriculture research and teaching brand;
- A global leader in agriculture, food, wine and natural resources science, exploring and informing critical national and global issues and challenges such as Australian agriculture industry competitiveness, food security, sustainable intensification of agricultural production, food, nutrition and health, advanced agricultural systems, and adaptation to climate variability and change;
- An international model of research, development, industry application and teaching through co-location of institutional partners, with capability in whole of value chain approaches from gene discovery to consumer needs;
- Renowned for high-quality education and training in agriculture, food and wine through undergraduate and postgraduate coursework and research degree programs;
- The centre of research capability for both grains and wine research within Australia.

12 world-class research organisations and centres

1100 research and technical staff

550 undergraduate students

295 postgraduate students

$100 million research income/expenditure per annum

$265 million research and teaching infrastructure

Waite-derived cereal varieties comprise approximately **80%** of southern Australian production

A high-impact publication record

Internationally recognised for delivering transformational and high impact agricultural technologies and systems

WRI highlights and key outcomes in 2014

In 2014, the WRI continued to support activities and initiatives aligned with its designated goals. Projects awarded WRI funding in 2013 were largely undertaken and completed during the 2014 calendar year and form the core of both 2014's progress and this document. All were designed to assist the University and the wider Waite achieve greater success across a range of measures.

WRI initiatives and targeted strategic investment over the last five years have been highly effective in producing significant outcomes for the University's School of Agriculture, Food & Wine and the Waite:

- Peer-reviewed publications are at their highest ever level, with 2014 proving a bumper year for the Waite;
- Annual competitive research grant income to the School of AFW is now well over $30m, having steadily increased during the past five years;
- Outcomes from graduates of the WRI's Research Leadership Development Program now include two successful ARC Centre applications and a range of other large grants;
- WRI-sponsored projects have assisted in securing significant further external funding and led to several manuscripts submitted to high-impact journals.

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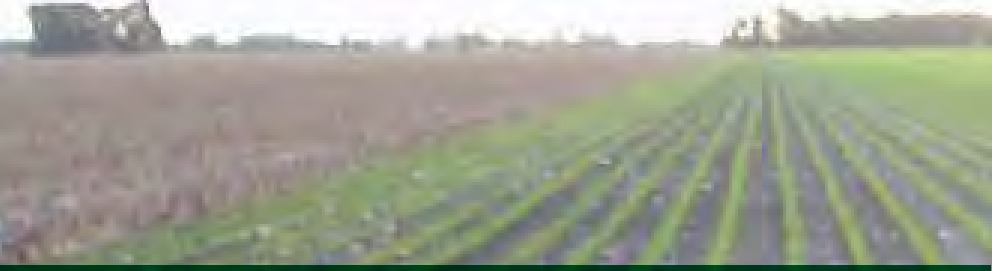


Major AFW funding successes in 2014

Projects that received WRI input/support/investment in development

* Graduates of the WRI's Research Leadership Development Program

Australian Research Council

Discovery Project grants

Project title: Engineered graphene-based nanofertilisers to improve crop nutrition

Recipients: Mike McLaughlin, Dusan Losic, Ehsan Tavakkoli, Jason Kirby

Funding amount: $636,992 (2015-17)

Project summary

Australia's grape and wine industry earns $4 billion annually (half as exports) and employs 60,000 - largely inregional areas. The industry's rise from the '80s via new plantings and production of well-made, full-flavoured varietal wines has faltered: key threats are climate extremes, water restrictions, a high dollar, markets access difficulties (eg China and India) and evolving consumer preferences. A new wave of innovation is needed to reinvigorate the industry. The ITTC for Innovative Wine Production will capture the expertise and facilities of Australia's key 'wine' universities along with grape, wine and allied companies to train researchers and yield applied research to reinstate Australia as a world leader in branded premium wines.

Project title: The role of the ammonium transport bHLHm1/AMF1 regulatory loci in plants#

Recipients: Murray Unkovich, Steve Tyerman, Brent Kaiser*

Funding amount: $454,700 (2015-18)

Project summary

Ammonium is an important nutrient source for plant growth and development. We have recently identified a new transport mechanism (AMF1) which mediates ammonium transport across legume root nodule cellular membranes. AMF1 was identified through a transcriptional interaction with a membrane localised bHLHm1 transcription factor. Both bHLHm1 and AMF1 belong to a unique chromosomal regulatory loci common across sequenced dicot plant species. This project will investigate the role of this loci in the regulation of ammonium transport in plants and the interacting genetic and biochemical signalling promoting the interaction.

We recently identified a new class of plant and fungal ammonium transport protein (AMF1) through an interaction with the soybean membrane localised bHLH

transcription factor (bHLHm1). Genetic analysis indicates both AMF1 and bHLHm1 are located at similar locations on eudicot chromosomes, highlighting an evolutionary conserved loci linked to ammonium transport. This project will define the activities that link this membrane based transcriptional cascade to ammonium transport in plants.

DECRA Fellowship

Recipient: Caitlin Byrt

Project title: Engineering enzymes controlling plant polysaccharide properties

Funding amount: $354,000 (2015-2018)

Project summary

Genetic control of the biosynthesis of the plant polysaccharide arabinoxylan is complex. The proposed project will combine transcriptomic, enzyme kinetic and glycomic data to characterise key enzymes that direct the flux of carbon from photosynthesis into arabinoxylan. The target enzymes synthesise and interconvert the precursor nucleotide sugars and their roles include a unidirectional enzymatic step. The function of these enzymes will be modified in transgenic plants to alter the properties of arabinoxylan. These data will define how the synthesis and interconversion of nucleotide sugars are regulated and how this controls the content and structure of arabinoxylan in economically important plants.

Increased consumption of the polysaccharide arabinoxylan is linked to a reduction in chronic disease. The properties of arabinoxylan influence the yield of energy-storing sugars released from plant biomass during digestion and industrial processing. This project will characterise and engineer enzymes that regulate the supply of the building blocks of arabinoxylan. Cereal grain arabinoxylan can be increased and the cost of processing of biomass can be decreased by modifying these enzymes.

Grains Research & Development Corporation

Innovation Investment grants

Project title: Trait discovery in wild barley using the nested-association mapping population HEB-25

Recipient: Tim March*

Funding amount: $750,000 (2014-19)

Project summary

Access to new sources of genetic diversity is vital for Australian barley breeders to develop new varieties with improved traits. Wild barley contains the largest pool of genetic diversity, however due to its unadapted 'weed like' nature increased resources are required to incorporate wild barley into mainstream breeding programs. As a result the diversity contained in wild barley has to date been largely unexploited.

This project will partner with the Martin Luther University in Germany, where they have recently developed a wild barley nested-association mapping population called HEB-25. To develop this population 25 wild barley accessions from across the Middle-East were crossed-pollinated to a modern barley variety. Through an international consortium this population is being mined for improved genetic variation for phenology, abiotic & biotic stress tolerance, and end-use quality.

Within this project the HEB-25 population will be imported into Australia to support trait discovery projects here. As part of the international consortium we will screen the HEB-25 population for drought tolerance using the Plant Accelerator in addition to disease resistances. Genetic analysis will be used to identify novel genes from wild barley that will facilitate the development of new Australian barley varieties with improved yield, disease resistance and quality.

R&D Tenders

Project title: Improving IWM practice of emerging weeds in the southern and western regions

Recipient: Christopher Preston

Funding amount: $2,548,338 (2014-2017)

Project summary

This tender will deliver new knowledge on the biology and management of summer weeds and winter weeds evolving resistance to multiple modes of action: fleabane, barley grass, brome grass, wild radish and Indian hedge mustard in Western and Southern Regions; feathertop Rhodes grass and windmill grass in the Southern Region and tar vine, button grass and milk thistle in the Western Region. The project will deliver information related to distribution, dispersal, emergence of summer weeds and the role of residual herbicides in their management. For winter weeds, the project will deliver information on the value of cultural and chemical controls for reducing weed numbers in crop. This is a collaborative project between the University of Adelaide, DAFWA, E. H. Graham Centre (NSW DPI and Charles Sturt University) and farming systems groups.

Australian Grape & Wine Authority (formerly GWRDC)

Research Grants

Project title: Translation of 'whole-of-production-chain' wine science research to industry outcomes

Recipient: Vladimir Jiranek*

Funding amount: $463,638 (2014-17)

Project summary

This grant funds a jointly-appointed senior postdoctoral fellow between UA and Charles Sturt University to build on existing collaborations and supports a number of the linked projects happening across the ARC Industrial Transformation Training Centre for Innovative Wine Production. This project seeks to translate and integrate knowledge and findings arising from the various streams of research at the Centre aimed at tailoring wine composition and modulating flavour and alcohol.

Dr Renata Ristic was appointed to this project, which will facilitate the collaborations and drive the translation of ITTC research outputs to industry-ready applications.

National Health & Medical Research Council

NH&MRC Career Development Fellowship

Recipient: Beverly Muhlhausler*

Project title: Breaking the Intergenerational Cycle of Obesity through Nutritional Interventions

Funding amount: $455,452 (2015-18)

The WRI's vision and objectives

Mission:

To deliver the science, education and innovation to transform Australian agriculture in global markets

Vision: Continued Excellence

"The University has all the elements of a global partnership at its Waite Campus, where research departments, research institutes and the R&D arms of government and business in the agricultural, food and wine field are co-located. In 2013, it will propose leverage of these organisations and selected international partners into a Waite consortium, which will likely become one of the most powerful concentrations of agriculture, food and wine research in the world."

The University of Adelaide Strategic Plan 2013-2023 "Beacon of Enlightenment"

The Waite Research Institute (WRI) is an initiative of The University of Adelaide to bring together world-leading researchers with a multi-disciplinary focus, to support collaboration between the Waite Campus partner and other organisations, to drive research for the benefit of Australia's agriculture, food and wine industries and to facilitate the career development of the next generation of Waite researchers.

In 2014, the WRI's activities and investments centred on the goals of:

1. Growing the quality of Waite science;
2. Enhancing the reputation of the Waite as "world leading";
3. Increasing collaboration across the Waite;
4. Developing Waite people for the future.

Staffing, Structure and Governance

Staff

Professor Mike Wilkinson

Director

Ms Carolyn Gadd

Executive Officer (0.6FTE)

Professor Rob Lewis

Strategic Projects Manager (0.4FTE)

Mrs Lisa Dancer

Administrative Officer (0.5FTE)

In 2014, the WRI became a designated unit within the University's School of Agriculture, Food and Wine with Professor Mike Wilkinson as Director. The WRI was supported by a small team of three staff (1.5 FTE) with strengths in strategic planning, research leadership and project management, science communication and research administration. Financial reporting responsibility for the WRI moved to the School of AFW.

No new proposals for funding or strategic initiatives were supported by the WRI in 2014.

Director's Report

Since the establishment of the WRI in 2009/2010, a time when there was a common misconception that the Waite was fading as a powerhouse of research excellence, the metrics of Waite research success and productivity have all shown steady and significant improvement.

The 2014 calendar year has seen the School of Agriculture, Food & Wine at the Waite surpass the $30m per annum mark in external research funding for the first time, no small achievement in the current political and economic environment.

The membership of the Waite Research Institute is all research-active staff and affiliates within the School of Agriculture, Food & Wine and its related Centres at the Waite. This group has not only brought in a record high total of grant funding, but also produced an impressive output of peer-reviewed publications in 2014. The graduates of the WRI's Research Leadership Development Program are leading the charge, with mounting anecdotal and qualitative evidence that this highly successful program has helped them overcome self-imposed and external limitations and perform at the highest level in a range of areas.

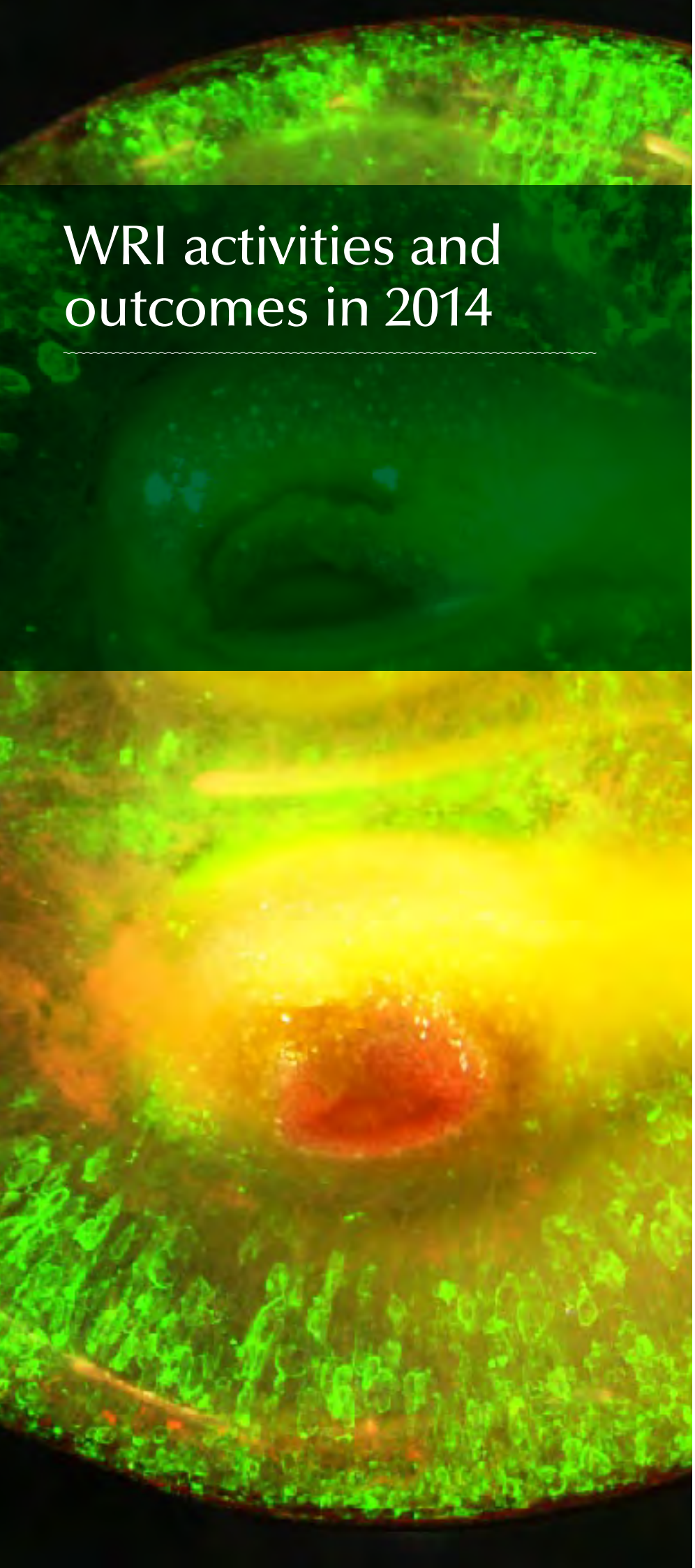
With the retirements and departures of a handful of the Waite's key research protagonists of the past two decades now having occurred, the WRI's investment in research leadership coaching for the most promising early to mid-career scientists within the School during the past three years has been perfectly timed. Addressing the succession planning issue and developing a new generation of Waite leaders was critical to the continued success of the Waite, which now seems both assured and in capable hands.

Student enrolments into undergraduate degrees hosted at the Waite Campus have also continued to improve, with first preference numbers well up for all agricultural science degrees in 2014. In addition, the establishment of the ARC Industrial Transformation Training Centre in Innovative Wine Production in early 2014 has seen the recruitment of high-calibre postgraduate students and postdoctoral fellows from a range of backgrounds and countries, further enhancing the agricultural science training credentials of the Waite in the national arena.

One of the key strengths and features of the Waite is that it is not simply a University campus, but a research precinct with an impressive array of high-quality institutions that collectively add substantially to the Waite brand and provide our students with an unparalleled opportunity to broaden their horizons beyond the academic setting. Much of the activity of the WRI over the past few years has therefore been focussed on strengthening links and communications between the Waite partner organisations to ensure that the Waite collective amounts to more than the sum of its parts, and these efforts continue.

In summary, 2014 was a lean and transitional year, focussed on completion of projects previously funded and maintaining a core suite of activities. I move on from the WRI secure in the knowledge that it has delivered disproportionately important and positive outcomes to the Waite and the wider University, for a relatively modest investment over its five full years of operation.

Professor Mike Wilkinson



WRI activities and outcomes in 2014

2014 was a consolidating year for the WRI, with no new activity or investments possible given existing budget commitments. Progress was restricted to those WRI-sponsored projects awarded funding during 2013, and maintaining a range of community engagement and communications activities such as Debate@The Waite and the *Harvest* radio program.

However, 2014 saw the previous year's strategic investment and breadth of activity bear some impressive fruit. With targeted use of resources in its five years of operation, the WRI has now generated, catalysed, supported or facilitated:

- timely transition between two generations of research leaders, ensuring succession from a small number of key senior researchers to a larger pool of rising stars;
- prestige grant and fellowship outcomes, including two Future Fellowships and a $2.4m ARC Industrial Transformation Training Centre;
- publication submissions to high-impact journals;
- improved communication and collaboration at the Waite, as demonstrated by multi-partner applications and bids for both internal and external opportunities.

The WRI's investments and their outcomes to date are listed on the following pages.

Picture: Shiraz grape berry with fluorescent overlay (courtesy of Siyang Liao, ARC Training Centre for Innovative Wine Production)

1 Growing the quality of Waite science

1.1 Collaborative and strategic initiatives

ARC Industrial Transformation Training Centre for Innovative Wine Production

The WRI's support of the $2.4 million ARC Industrial Transformation Training Centre for Innovative Wine Production continued through the Centre's first year with a contribution towards the recruitment and development of postdoctoral research staff and PhD students, a phase which has now been completed. The Centre involves no less than 12 partner organisations, and will provide new knowledge, methods and technologies, as well as skilled researchers to work at the interface with industry, to help the wine sector tackle challenges such as climate change, compressed harvests, water scarcity, changing consumer preferences, and reducing alcohol levels.
See **www.adelaide.edu.au/ittc-iwp/** for more details on the ARC Training Centre.

Ongoing support of the Waite node of Adelaide Microscopy

The Waite node of Adelaide Microscopy opened in September 2013 and has since provided an invaluable local service to Waite researchers. The WRI co-funds the annual costs of staffing Adelaide Microscopy at the Waite with a full-time technical officer/ supervisor.

A Nikon SMZ25 stereo microscope purchased with WRI funds awarded in a competitive equipment round in late 2013 was installed at the Adelaide Microscopy Waite Facility in January 2014. During 2014, this microscope supported over 10 research staff and HDR students, from the CoE Plant Cell Walls, ACPFG, Plant Physiology (Viticulture and Horticulture), SARDI and CSIRO, with individual training and maintenance provided by Adelaide Microscopy staff. Usage uptake increased towards the later part of 2014 and continues to grow. The high publication quality bright field and fluorescent images along with the extended depth of focus, time course, measurement and image stitching applications would not have been achieved by these users without the SMZ25. The stereo microscope proved to be flexible across a wide range of magnifications, applications and specimens. These included a barley germination time course video, snail heart beat development time course video, barley and wheat meristem development, grape vine bud development, island fly gut images, wheat and barley grain autofluorescence, grape cell death, and root nematode fluorescent stains.

In addition, a zooming port and camera funded by the WRI was added to the A1 confocal (compound) microscope in 2014. The camera takes far superior images to the old imaging microscope that had reached the end of its life. It has been successfully used for fluorescence, bright field and DIC, for example imaging chromosome spreads at high magnification.

Genome Australia - next generation sequencing in partnership with AGRF

During 2014, the WRI was involved in facilitating discussions between the Australian Genome Research Facility (AGRF) and various University and other partners to build the case for some of the available Federal (post-NCRIS) funding to flow to SA. The Agriculture and Environment node of a new national genome network supporting Australian science into the future now looks likely to be located at the Waite. Formal negotiations with the Australian government also took place in late 2014. These discussions involved contributions from senior researchers using genomics in the biomedical, agricultural and environmental fields.

Supporting bilateral partnerships

As part of a larger program of exchange and partnership between The University of Adelaide and North Carolina State University, discussions with representatives of NCSU continued in 2014 on arrangements for a 50/50 matching funding program to facilitate joint projects aligned with the Waite's strategic directions and delivering mutual benefit and complementarity. The WRI provided support to these meetings and has committed funds to the development of this partnership via travel support and seed funding for projects.

In addition, the WRI's Director, Professor Mike Wilkinson, played a key role in the early development of The University of Adelaide's partnership with Shanghai Jiao Tong University, which led in late 2014 to the joint appointment of Professor Dabing Zhang and the establishment of a joint laboratory in Plant Science and Breeding at the Waite's Plant Genomics Centre.

1.2 Sponsored project outcomes

In mid-2013, the WRI awarded funds to four large projects designed to lead to high-impact publications. These were selected from a strong field of 19 applications by the WRI's Science Advisory Committee via a merit-based, two-stage application process. Most of these were longer-term projects that ran well into 2014.

The final outcomes of these projects are summarised on the following pages.

High impact publication projects - awarded May 2013

Project 1

Honeybees deliver targeted control of Botrytis bunch rot in grapes

Investigators: Dr Katja Hogendoorn, Dr Cassandra Collins, Professor Eileen Scott

Funding awarded: $146,000

Background

Bunch rot caused by the fungus *Botrytis cinerea* is a major disease of grapes, causing millions of dollars of crop loss and reducing wine quality. Infection often occurs at capfall, when necrotic floral tissue provides an entry point for the fungus, which then remains latent until veraison.

Figure 1: Experimental cages at the Coombe vineyard, Waite Campus, used to test the delivery of biocontrol agents by bees to grapevine flowers

Growers routinely spray chemical fungicides to prevent infection during flowering. B. cinerea exhibits resistance to numerous fungicides, making the use of biological control an increasingly attractive and sustainable option.

Targeted fungicide application using bees is expected to lead to:

a) Cheaper disease control, by reducing the use of fungicide, fuel and machinery;

b) Improved soil health by avoiding (1) off-target delivery of fungicide to the soil and (2) soil compaction caused by driving the spray rig through the vineyard

c) More sustainable production systems, by (1) reducing spray drift and run-off into aquatic systems, (2) delaying the emergence of resistance to fungicides in B. cinerea by reducing selection pressure and (3) by encouraging activity of bees in vineyards.

Overseas, the delivery of fungicides by bees to flowers of strawberry, apple, pear and several berry species is cost-effective compared with boom spraying for the control of Botrytis rot and other fungal diseases. However, the potential to use honeybees for the delivery of fungicides to grape flowers has not been investigated or published.

Aims

The project intended to:

- Further investigate and quantify bee visitation to grape flowers including uncapping behaviour;
- Study efficacy of delivery of an antifungal agent in the field;
- Experimentally assess the effects of both bees and antifungal agent on incidence and severity of Botrytis bunch rot, both as a latent infection and as bunch rot post-veraison;
- Investigate the effect of bees and bee delivery of antifungal agent on yield and qualitative aspects of grape juice (pH, TA, Brix);
- Produce a manuscript with an expected completion date of 30 October 2014.

Results

Bee behaviour

The novel foraging behaviour of honeybees was confirmed and documented, showing that by uncapping grape flowers, the bees can obtain more pollen than they would otherwise. Removal of the operculum and of bunch trash can also help in the control of the development of millerandage (undeveloped berries) and diseases such as Botrytis bunch rot.

Delivery in the vineyard

The bees delivered the biocontrol agent in all vineyards, but delivery was patchy, and only just as good as spraying a suspension of the biocontrol product at the recommended rate close to the hive. Further evaluation, currently underway, will allow assessment of economic viability of entomovectoring in grapevines.

Experimental assessment of delivery and control

The experimental assessment of the efficacy of control in the cages was hampered by the conditions after veraison, which were either too conducive (Lenswood) or not conducive enough (Waite) for disease development.

Effects on yield and grape juice quality

In the cages, no effects were found of either bees or antifungal agent on yield or chemical aspects of grape juice.

Outputs and outcomes

Papers

A manuscript about the foraging behaviours and the significance of cap removal to the benefit of bees is on the being submitted to *Apidologie*, the leading journal in the field of bees.

Oral and poster presentations

Several oral and poster presentations have been made:

Professor Eileen Scott presented early findings at a workshop associated with the Australasian Plant Pathology Society biennial conference in Auckland in November 2013;

Dr Katja Hogendoorn presented findings and methods at the AFW Research Day and to a McLaren Vale Vignerons group.

Poster presentations were also made at the congress of the Australian Entomological Society (Canberra, September 2014) and at the Almond Industry Conference (Adelaide, October 2014).

Distinguished visitors

In February 2014, the project attracted Prof Heikki Hokkanen, University of Helsinki and an international expert on entomovectoring, to Adelaide. He came as a distinguished speaker to present the prestigious Bob Symons lecture at the Waite.

Students

The project attracted two summer scholarship students in 2014 (Christopher De Ieso, a level II BAgSc student, and Isabel Chan, a B Biotechnology student), as well as Viticulture and Oenology honours student Philip Sweeney (2014), who achieved first class honours for his work on bees and Trichoderma.

Further funding

This WRI project led directly to a successful application to DAFF for an Innovation grant, with Katja Hogendoorn as Chief Investigator and Mike Keller and Eileen Scott as co-investigators. This grant ($628K) was awarded in May 2014 for a two-year project to promote entomovectoring in cherries, grapevines and possibly almonds and peaches/nectarines.

Outlook

While the future of entomovectoring for the grape industry is uncertain, development of entomovectoring in other horticultural industries is currently well underway and it is unlikely that this would have happened without WRI support. Thus, the initial support from the WRI has been crucial in securing substantial funding for further collaborative research and development that will see the introduction of entomovectoring as a novel, profitable and sustainable method for the delivery of biological control in a wide range of Australian horticultural industries.

Project 2

The discovery and characterisation of GABA-gated ion channels in plants?

Investigators: A/Professor Matthew Gilliham, Dr Bo Xu, Dr Sunita Ramesh, Professor Steve Tyerman

Funding awarded: $198,600 (over 18 months)

Background

The non-protein amino acid, gamma-aminobutyric acid (GABA) is a major inhibitory neurotransmitter in animals that acts as a signal by regulating ion flow across cell membranes via two classes of receptors, the GABAA and GABAB. GABA also rapidly accumulates in plant tissues in response to biotic and abiotic stress, and regulates plant growth. Until now it was not known whether GABA exerts its effects in plants through the regulation of carbon metabolism or via an unidentified signalling pathway. We had preliminary and novel evidence to suggest that GABA was acting as a signal in plants through regulating the activity of a family of anion channels (the Aluminium-activated anion transporter (ALMT) family), and that this was essential in regulating plant tissue growth.

Significance

Rapid increases in GABA concentration occur in plants in response to a multitude of stresses including extreme temperatures, dehydration, salinity, oxygen stress, mechanical damage, acidosis, virus infection and defence against herbivory. Elevated GABA concentrations reduce root growth, whilst GABA gradients are required in the female reproductive tissues to guide pollen tubes to the ovary to ensure successful fertilisation. This has led to speculation that GABA signalling occurs in plants, as it does in mammals. However, as no molecular components for GABA signalling in plants have been identified, and there are no plant homologs of mammalian GABA receptors, it has remained unclear whether changes in GABA concentration constitute a metabolic response or an adaptive signal. We have identified a range of Aluminium-activated malate transporters (ALMT) as key transducers of GABA signalling in plants. ALMT form a large multigenic anion channel family exclusive to plants with multiple physiological roles and discrete expression patterns. Our works demonstrates the impact of GABA-regulation of ALMT activity in wheat roots during pH and aluminium stress. More broadly, our findings have revealed that GABA-mediated regulation of ALMT proteins underlies a novel-signalling pathway that has the potential to translate changes in the concentration of this plant stress metabolite into physiological outputs throughout the plant.

Aims

The primary aim of this WRI-funded project was to maximise the chances of publishing these findings in a Nature series journal. A second aim was to investigate further signalling roles of GABA in plants through their interaction with ALMT proteins for a second high impact publication. Thirdly, the preliminary results from this research were pitched to the ARC as part of core to a research stream in an ARC Centre of Excellence bid, so were linked to the successful outcome of that funding bid.

Outputs and outcomes

Further funding

ARC Centre of Excellence funding of $4,931,598 was awarded to CIs Gilliham and Tyerman in December 2013 from 2014-2020. This has allowed this research stream on GABA to be continued, now in collaboration with the groups of other COE CIs.

Papers and patents

A provisional patent for the discovered GABA binding motif was filed December 2013 (PCT07083).

The initial publication was accepted on condition of minor revisions that were requested by the Editor for publication in the *Nature* series journal; this manuscript was to be resubmitted in May 2015. Publication title: GABA signalling modulates plant growth by directly regulating the activity of plant-specific anion transporters.

Whilst working funded by the WRI, Dr Bo Xu spent a week preparing data for an additional publication for the third highest-ranked, international peer-reviewed plant journal, *Plant Journal* (IF=7.5). Byrt CS, Xu B, Krishnan M, Lightfoot D, Athman A, Watson-Haigh NS, Jacobs A, Plett D, Munns R, Tester M, Gilliham M. (2014) The Na+ transporter, TaHKT1; 5-D, limits shoot Na+ accumulation in bread wheat. *Plant Journal* 80:516–526.

A/Professor Gilliham was invited to submit a review on this area of work for Molecular Plant (IF=6.6), submission date July 2015.

Postdoctoral training and international collaboration

Dr Bo Xu has now been trained in the laboratories of leaders in the field of plant cell physiology, Enrico Martinoia (h-index = 62, citations 11,495; Zurich, Switzerland) and Rainer Hedrich (h=index 62, citations 11,861; Wurzburg, Germany).

A/Professor Gilliham visited the Martinoia lab in December 2014 and there are strong, ongoing collaborations with both the Martinoia and Hedrich labs.

Invited oral presentations

A/Professor Gilliham gave invited talks on this work at the International Conference on Arabidopsis Research, Sydney in July 2013 and the Society for Experimental Biology Plant Transport Group, Glasgow, UK, in December 2014.

Other invited presentations included:

- A/Professor Gilliham - Institute of Crop Sciences, Chinese Academy of Agricultural Sciences, Beijing, China, January 2014
- A/Professor Gilliham - University of Cambridge, UK, December, 2014
- A/Professor Gilliham - John Innes Centre, Norwich, UK, December, 2014
- A/Professor Gilliham - University of Zurich, Switzerland, December 2014
- Professor Tyerman - Flinders University, March 2014.

Future work and planned activities

Dr Xu's work in Germany will finalise experiments that will provide the basis for a further manuscript submission at the end of 2015.

Dr Xu will also submit a DECRA application based on his findings in March 2016.

Project 3

Rethinking the nature of soil organic P: A new model of the terrestrial P cycle

Investigators: Dr Ron Smernik, Dr Ashlea Doolette and Dr Tim McLaren

Funds awarded: $73,500

Background

Phosphorus (P) is a key element for sustaining life. Phosphorus is also central to looming resource and environmental concerns, with dwindling sources of minable P on one hand and environmental damage caused by P losses from agriculture on the other. Phosphorus cycles between living and non-living forms and between organic and inorganic forms. In many terrestrial ecosystems, soil organic P (SOP) is the largest single pool of P. The prevailing theory is that the majority of SOP consists of phytate, a P-rich organic molecule used by plants for P-storage in seeds, which accumulates in soil because it binds to soil minerals, protecting it from microbial degradation.

In previous research, newly developed NMR techniques demonstrated that many Australian soils in fact contain little or no phytate, and that when phytate is added to soil it is rapidly degraded. This project sought to develop and investigate a radically different explanation for SOP stabilisation in soil. This alternate new paradigm invokes a different stabilisation mechanism for SOP in which P is incorporated into large, polymeric organic macromolecules through the process of humification.

As conceived, this project had two parts. The first was to carry out molecular size separations of SOP to confirm the existence of organic P in large humic molecules. The second was to apply our new NMR analyses to the widest possible variety of Australian soils in order to establish whether "humic P" is dominant in all Australian soils. However, by the time the project started, we had already made significant advances on the second part and had established a hypothesis that climate was the key driver of organic P composition and that the apparent contrast between Australian and overseas soils reflected the fact that most overseas soils for which NMR data had been discussed were from cool, wet climates, whereas most of our analyses involved Australian soils from soils that were at least seasonally warm and dry. We thus resolved to include analyses of overseas soils from warm, dry climates in part 1 of the study and to source Australian soils from cool, wet climates for part 2 of the study.

Part 1: Molecular size separation

In this part of the study, we developed an ultrafiltration methodology for separation of soil extracts into <10kDa (filtrate) and >10 kDa (retentate) fractions and applied it to five soils from around the world, ensuring that we included a soils from a range of climates. This proved very successful and we have now submitted a manuscript to Nature Geoscience. The central data of that manuscript is the figure reproduced below. It confirms that: (i) the cooler climate soils (those from France, Germany and Sweden) do indeed contain more low molecular weight organic P molecules (these give rise to the sharp features in the NMR spectra of the whole extracts and <10kDa filtrates), including phytate and its isomers, whereas the warmer climate soils from Australia and southern USA contain more low molecular weight organic P (which gives rise to the broad feature seen in all spectra); and (ii) that the spectrum of the high molecular weight (>10 kDa retentate) fraction of every soil is dominated by the broad feature, just as we predicted. Other researchers in the area have doubted both the existence of this feature and our suggestion that it represented high molecular weight material.

Part 2: Analysis of Australian soils from "cool" climates

As discussed above, a central tenet of our new paradigm is the influence of climate on organic P composition. In the context of Australian soils, the dozens of soils we had already analysed were almost exclusively agricultural soils from cropping or pasture areas that experience warm, and at least periodically dry, summers. We thus sought to source samples from the Australian Alps, to provide those soils least likely to experience warm, dry conditions. Whilst we were unable to gain permission to sample in Mount Kosciusko National Park, we were able to access five such soils from the CSIRO archive. Analysis of these soils confirmed our hypothesis: these five soils indeed contain a greater proportion of low molecular weight organic P molecules (i.e. sharp features in the NMR spectra) than any of the Australian soils previously analysed and are in fact quite similar composition to the "cool climate" European soils discussed above in Part 1 of this project. We are currently preparing a manuscript on these results that we expect to submit to Soil Research.

Part 3: An explanatory mechanism

Although not part of the project as proposed, the success we had allowed us to further pursue the mechanisms involving organic P transformations that underlie this project. In simple terms, P cycles between living and non-living forms and between organic and inorganic forms. In many terrestrial ecosystems, soil organic P (SOP) is the largest single pool of P. A small fraction of this is contained in the cells of organisms living in the soil (e.g. plant roots, bacteria, fungi etc.), but the vast majority is non-living. The original source of this non-living organic P is living cells, but through either cell death or exudation from cells, these molecules have made their way into the soil itself. Note that in this model, the only direct transitions between living and non-living pools are those that preserve chemical form (i.e. organic or inorganic). Note also that there is no direct route from non-living organic to living organic (i.e. it assumed that organisms can only directly assimilate inorganic P) and there is no direct route from non-living inorganic to non-living organic P (i.e. it is assumed that organic P is only synthesised inside cells). The vast majority, if not all, scientists in our area would currently accept this basic paradigm.

A key feature of this traditional view is that since organic P is only synthesised inside cells, all forms of organic P found outside the cell should also be found inside the cell, although their relative proportions could differ if some forms decompose more quickly than others. Crucially, the broad feature we identify in NMR spectra of soils, which we have proven in Part 1 of this project to include high molecular weight material, has never been detected in biomass, either of plant or microbial origin.

In our alternate model of the soil P cycle, the non-living organic P is split into separate humic and non-humic pools (Figure 1). There are two possible ways in which the humic P could be formed: either it is synthesised from non-humic organic P molecules (path 1) or it is synthesised by phosphorylation of OH groups present on humic molecules by inorganic P (path 2).

In experiments that go beyond those

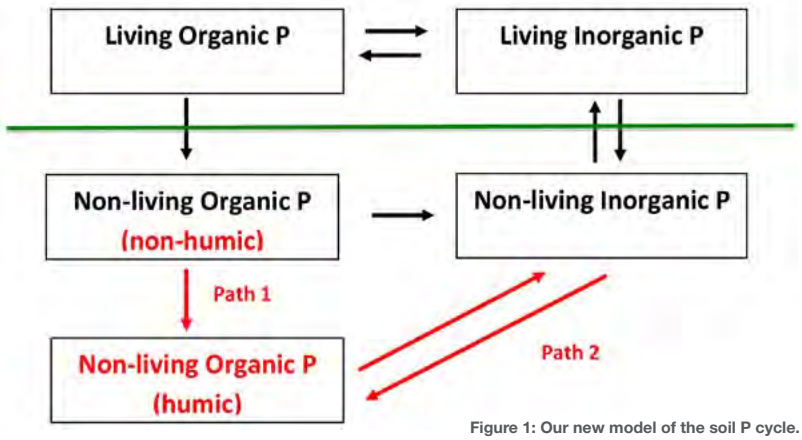


Figure 1: Our new model of the soil P cycle.

described in the original proposal, we have now established that "Path 2" is not only viable, but is also favoured under relatively dry conditions and proceeds at a more rapid rate in warm conditions. Crucially, this provides a mechanism explaining our empirical observation that organic P composition in soils is controlled by climate, with "humic P" dominating in soils that experience warm dry conditions at least seasonally. We are working toward completing this aspect of our investigations and expect to publish it in at least one further journal article. We also intend to continue pursuing this line of research, including through an ARC Discovery proposal submission in 2016.

Outputs and outcomes

In summary, this has been a very successful project. A first paper, "Complex forms of organic phosphorus: a major but overlooked component of soil phosphorus" (Authors: Timothy I. McLaren, Ronald J. Smernik, Michael J. McLaughlin, Therese M. McBeath, Jason K. Kirby, Richard J. Simpson, Christopher N. Guppy, Ashlea L. Doolette and Alan E. Richardson) has already been submitted to a high-impact journal, *Nature Geoscience*, and preparation of a second manuscript (for *Soil Research*) is underway. These manuscripts are the culmination of the two parts of the project as originally conceived. In addition, we were able to carry out further experiments during the course of the project and although these were not completed before WRI funding ceased, we have been able to continue with this research and fully expect this additional work to result in at least one further publication. Furthermore, we foresee that the research carried out here will underpin an ARC Discovery proposal in the near future.

In particular, we must highlight the importance of this project to the two early career researchers involved (Ashlea Doolette and Tim McLaren); beyond the three publication outputs, it has provided them a relatively rare opportunity to demonstrate their research prowess in a short and low-cost project, to progress an original and radical research idea toward a larger external grant proposal and to get "runs on the board" in attracting research funding.

Project 4

How Nutrients Regulate the Microbiome-Genome Interactions in the Maturing GI tract of Preterm Infants

Investigators: Muhlhausler, Penttila, Bianco-Miotto, Bent, Gibson, McPhee, Collins, Zhou, Makrides

Funds awarded: $70,000

Background

It has long been recognised that the gastrointestinal tract of humans and animals is host to a vast number of bacterial species, which outnumber the cells of the organism by around 100 fold. Importantly, there is now compelling evidence that the composition of the microbiota in the human gastrointestinal tract (the microbiome) plays an integral role in human health and disease and that altering its composition can have a profound impact on an individual's metabolic and immune profile.

Existing studies suggest that early infancy is a critical period for the development of the microbiome, the gastrointestinal tract and associated mucosal immune system. While a number of factors have been identified which can modulate the composition of the microbiome of the infant, including caesarean delivery and breast vs formula feeding, there is a limited understanding of specific nutritional factors in the early postnatal period which impact on this development, and how the development of the microbiome relates to markers of gut maturation and associated clinical outcomes. The microbiome has a particularly critical role in pre-term infants, who have a less mature GIT and associated immune system that full-term infants, and who are at significantly increased risk of life-threatening diseases resulting from increased inflammatory processes.

The overall aim of this research is to determine factors in the early postnatal period which contribute to the development of the microbiome in pre-term infants and to identify whether supplementing the pre-term infant diet with the omega-3 fatty acid DHA can promote the development of a microbiome and associated mucosal immune system.

The specific aim of the seed-funding proposal supported by the WRI was to establish and optimise the methodology for the isolation of high-quality DNA, RNA and epithelial cells from stool samples collected from pre-term infants which could then be applied to address the question outlined above.

Sample Collection

- Ethical approval was obtained from the WCH ethics committee to collect stool samples from pre-term infants in the neonatal intensive care unit (NICU) at the Women's and Children's Hospital, Adelaide. The procedures for stool sample collection and transfer to the laboratory were established and optimised, and it was determined that obtaining optimal sample quality relied on transporting samples to the laboratory within 4 hours of collection.
- A total of 59 stool samples were collected from a total of 34 preterm infants born between 24 and 34 weeks, at various time points across the early postnatal period.
- Separate ethical approval was obtained to collect stool samples from infants enrolled our N3RO randomised controlled trial involving supplementing very preterm infants (born <29 weeks) with the omega-3 long chain fatty acid (n-3 LCPUFA), docosahexanoic acid (DHA) from birth to 36 weeks post-menstrual age. We have collected samples from 39 of these infants to date.

Method Development and Optimisation

- Three commercially available kits for stool DNA/RNA extraction were tested and the yield and quality compared. As a result of this series of experiments, we successfully optimised a method for obtaining high quality DNA and RNA from stool samples collected from pre-term infants.
- For DNA extraction we used the PowerSoil

DNA extraction kit and achieved a yiled of 0.88 to 31.20 mg DNA/g stool (average=6.7 mg/g). For RNA extraction we used the PowerMicrobiome RNA extraction kit and achieved a yield of 3.30 to 280 mg RNA/g stool (average=63.1 mg/g).

- We successfully developed a method for isolating epithelial cells from pre-term stool samples. For cell extraction we used a Percoll gradient cell differentiation technique: We yielded between 1x104 to 2x105 cells per stool sample.
- We confirmed that the quality of these samples, and the yield obtained, were more than sufficient for down-stream genomic/epigenomic applications.
- Using qRT-PCR, we confirmed that we were able to isolate both human and bacterial RNA/DNA from the stool samples and epithelial cells –enabling us to both characterise the microbiota in the pre-term infants, and also to evaluate the epigenome/genome of the cells lining the gastrointestinal tract.

Outputs and outcomes

Using WRI seed funding we successfully established methodologies for isolating high-quality genetic material and epithelial cells from stool samples from pre-term infants. Critically, we are the first group in the world to be able to demonstrate that we can isolate intact epithelial cells from stool samples in preterm infants, and use the RNA/DNA isolated from these cells to undertake downstream analysis and ideally placed to apply these methods to achieve high-impact publications.

We have established successful collaborations with A/Professors Geriant Rogers (SAHMRI), an expert in the gut microbiome and David Lynn (SAHMRI), an expert in applying RNAseq to characterise systemic immunity in blood and tissues. A/Professor Rogers has used the DNA samples collected from the preterm infants characterise the microbiome in 34 preterm infants over the first few weeks after birth, while A/Professor Lynn has undertaken RNAseq analysis of blood samples collected from this same infant population to assess systemic immunity. These data are currently being collated and will form the basis of a publication to be submitted in the first half of 2015.

While we have not yet secured funding for the further expansion of this project, despite attempts in 2014, we have a pending application and several more planned for 2015. We are confident that, now we have preliminary data which clearly demonstrate the feasibility of our proposed study and evidence of our successful collaboration, we are in strong position to secure significant research funds over the coming 12-18 months.

In the meantime, we have utilised limited internal funding to undertake collection and initial processing of serial stool and matching blood sample from preterm infants enrolled in our NHMRC-funded randomised controlled trial of DHA supplementation in the immediate postnatal period (N3RO). We are seeking funds to undertake detailed mapping of the gut microbiome of these infants, undertake genetic/epigenetic and immune profiling of the gastrointestinal epithelial cells and RNAseq to investigate markers of systemic immunity in the peripheral blood leukocytes. This will enable us to realise our ultimate goal of assessing not only longitudinal changes in microbial colonisation patterns in early infancy, but also to determine whether a nutritional intervention (DHA) has the capacity to alter the pattern of microbial colonisation, and thereby promote gut immune maturation and suppress systemic inflammation.

Overall, the seed funding provided by WRI has underpinned the establishment of a new research area within FOODplus, which is at the forefront of Microbiome Research. The preliminary data being generated by both A/Professors Geriant Rogers (microbiome) and David Lynn (systemic immunity) are extremely exciting and we are confident of securing high-impact publications from the work already undertaken during the course of 2015, and of securing funding for the further expansion of this research area.

Platform projects – awarded September 2013

In June 2013, the WRI invited applications from Waite researchers aimed at utilising shared Waite platform technologies and infrastructure to significantly enhance and complete existing projects and build collaboration on the Campus. This initiative was designed to encourage applications in the $10-15K range for projects where existing data required further work to generate a high-impact publication or to prove a concept for patent filing. The use of Waite facilities such as Adelaide Microscopy, Waite Analytical Services, Australian Genome Research Facility (AGRF), Metabolomics Australia, the Plant Accelerator or MiSeq Next-Gen sequencing was considered mandatory for these applications.

Three projects were funded (from a total of seven applications) and the reports and outcomes from these follow:

Project 1

We prefer them old: Epigenetic control of wine quality in response to grapevine age

Investigators: Drs Cassandra Collins, Roberta De Bei, Carlos Rodríguez López, Jimmy Breen

Funding Amount - $14,560

Background

Wines made from grapes produced on old vines often attract a premium bottle price. Anecdotal evidence from winemakers suggests that ‘young’ grapevines lack the complexity and quality of ‘old’ vine wines. There is increasing evidence that epigenetic mechanisms such as DNA methylation contribute to important agronomic traits. While genetic traits are fixed during the life cycle of an individual, environmental exposure and stochastic processes during development lead to changes in DNA methylation, which can induce new phenotypes. This study aimed to understand if age induced methylation variation contributes to changes in wine chemical composition and sensory attributes.

Materials and Methods

Five Barossa Valley vineyards containing an “old” block (+100 years) and a “young” block (up to 30 years) planted from cuttings taken from the “old” block were selected and sampled. Final vineyard selection was based on the uniformity between age groups for soil, vine health, aspect and management. Three replicate blocks containing 4-5 vines were established for each age group at each site and have been assessed and sampled from for three consecutive vintages. At harvest, berries were selected for chemical, winemaking and sensory analysis. Sugar, acidity, colour, tannin and phenolic levels were measured on berries and wines. Descriptive analysis on berries and wines

was conducted by a trained panel to determine if aroma and flavour attributes provide enhanced quality to wine from old vines.

Leaf and berry samples were collected from three "old" vines (129 years old) and three "young" vines (13 years old) for molecular analysis at three critical phenological stages of grapevine development during season 2013/2014. Three replicate DNA/RNA extractions from each of the different tissues/developmental stages of six vines were undertaken and sequenced to understand the non-genetic effect that vine age has on wine quality. Whole Genome Sequencing (WGS), Whole Genome Bisulfite Sequencing (BS-WGS) and comparative analyses were carried out to identify differentially methylated genes and their effect on biosynthesis pathways. Candidate gene expression changes were then confirmed using NGS RNAseq.

Overview of results

Principal component analysis (PCA) was used to assess the interactions between vine age and the significantly different chemical and sensory characteristics of Shiraz wines made in 2014. PC1 and PC2 accounted for over 92% of the variability in the dataset and age clustering is evident. Generally, wines from older vines had greater levels of skin and seed tannins and panelists rated these wines as being more complex, savoury and having greater red fruit, fresh fruit and coarser tannin structure than younger wines. Young vine wines were characterised has having higher levels of total anthocyanins, phenolics and epicatechin compared to old vine wines (Figure 1).

WGS achieved an average coverage of 18X and 92% of genome coverage per sample. Genetic distances between old/young Shiraz and Cabernet-Sauvignon samples were estimated comparing the re-sequencing data (Figure 2). Varietal SNP variation was observed over reference samples (Cabernet Sauvignon and Shiraz) (Figure 2a) and but little genetic variation was observed between Shiraz old and young samples (Figure 2b).

BS-WGS achieved a mapping efficiency range of 25.1-52.9% between biological replicates from sampled sites. Global DNA methylation levels were higher in young vine leaves and skins and lower in seeds at veraison. No significant global differences in DNA methylation were observed in any of the two tissues screened at harvest (Figure 3).

Locus specific differences in gene methylation levels and gene expression were calculated by grouping samples using different levels of hierarchy. In short, samples were first separated into two age groups (old and young), then by developmental stage (E-L 7, E-L 35, E-L 38), and finally by tissue (leaf, grape skin and seed). Genes presenting differential expression and differential methylation (Table 4) between groups were selected for further analysis.

Metabolic pathways generating metabolites shown to be differential between old and young wines and berries during the sensory and chemical analysis were cross-referenced for the presence of genes showing differential expression/methylation. Significant gene expression and promoter CpG methylation was observed in key flavonoid pathway genes that contribute to wine characteristics observed in sensory evaluation (Figure 5).

Delays to completion

The project team have worked well together to collect and analyse the data to complete this project. All sampling and processing for chemical, sensory and molecular analysis was performed on schedule. Unfortunately due to equipment breakdowns, sequencing was delayed until January 2015. Additional funding was also required to pay for sequencing.

Outputs and outcomes

Three papers are in preparation from work undertaken during this project, all due to be submitted in mid-2015.

1 Nature Communications/New Phytologist/PLOS Genetics

This paper will describe the relationships between chemical composition, sensory evaluation and methylation as they relate to specific chemical pathways linked to colour and flavour development in grape berries and wine.

2 Journal of Experimental Botany/BMC Plant Biology

This paper will compare the methylomes and gene expression of the different grapevine tissue types – leaves, berry skins, seeds.

3 PLOS One/Epigenetics

This paper will use comparative epigenomic analysis to align methylomes of horticulture and agricultural crops such as rice, grapevine and Brassicaceae species.

Collaboration with other academics and researchers at The University of Adelaide and the Australian Wine Research Institute occurred during this project and will contribute to these publications.

In April 2014, Mr Dylan Grigg joined the team as a PhD student and is investigating whether vines of different ages and wines made from them differ in their physiological, genetic and sensory components of quality that may be influenced by vine age.

The combination of this work and the previous two seasons will form a fourth paper to be submitted late in 2015 by the project team.

4 Australian Journal of Grape and Wine Research

This paper will compare vine growth, berry and wine chemistry and berry and wine sensory assessments over the last three growing seasons between the five Barossa sites as they relate to age.

Future funding

Due to the success of the project team and the breadth of skills and expertise that each team member brings we are now putting together a project suitable for the next ARC Linkage funding round. Negotiations are currently underway with potential industry partners. The team will also be applying for further funding from the AGRF Pilot program in Genomics funding for Agriculture and Environment Sectors due in May 2015 to investigate the relationships between climate, soil and management and how they affect wine quality (terroir) using genetic, epigenetic, metagenomics and metabolomic approaches.

Project 2

High resolution visualisation of fine roots in soil amended with novel fertiliser formulations

Investigators: A/Professor Ann McNeill, Professor Mike McLaughlin

Funding Amount: $16,396

Project aims

This project aimed to use the micro-CT facility (Skyscan 1076) offered by Adelaide Microscopy to produce high-resolution images of the response of wheat seedling roots to novel micronutrient coated fertilisers currently being developed by the Mosaic Fertiliser Company. It also aimed to compare software for root visualisation in soil developed at The University of Adelaide

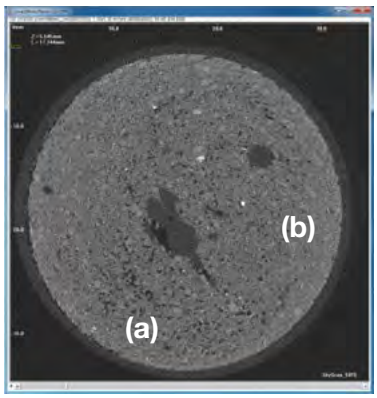
(RootViz) with software developed in the UK (RooTrak) and identify the optimum approach.

Outputs and outcomes

Progress in this project has been much slower than planned due to the scanning equipment available in Adelaide (Skyscan 1076) being less than ideal for the proposed work. This meant that optimisation for suitable image generation proved far more time consuming and difficult than anticipated. Nevertheless protocols for scanning were devised and a pilot experiment was run by a consultant to the project (Dr Rob Davidson).

During the second half of 2014, the main experiment was completed. This included 3D micro-CT scanning, sampling of plant materials (shoots and roots), ICP analysis and 2D flat-bed scanning of cleaned and washed roots. The outputs from the CT scanning in the main experiment of intact cores containing plants grown using different forms of boron fertiliser are now being processed. Segmentation is proceeding well, but reconstruction into 3D images is another time-consuming exercise given the size of the images and this process is ongoing. 2D scans of the root systems of the plants that were removed from the soil in the intact cores after 3D scanning have also recently been generated using WinRhizo and these will shortly be analysed.

The image below shows clearly the seed (a) in the centre and a toothpick (b) in the north east side of the core (approx. 2 mm in diameter). It's also possible to see layers reflecting slight variations in the density of the soil.



A manuscript arising from this project is in development, with submission to PNAS planned by the end of 2015.

Project 3

A multifunctional borate transporter from barley mediates efflux of anions and exhibits channel-like characteristics

Investigators: Professor Maria Hrmova; team members – Yagnesh Nagarajan, Nadim Shadiac, Julie Hayes, Tim Sutton, Steve Tyerman, Gordon McPhee, Nicolas Voelcker, Haydyn Mertens, Yaroslava Yingling

Funding Amount: $15,000

Aims

The overall aim of the project was to characterise molecular and structural properties of a barley efflux borate transporter (HvBot1) that is considered to be the one of the key determinants mediating tolerance to high soil boron toxicity. These data address how a cereal borate transporter mediates its biological function at the molecular levels.

The WRI award enabled completion of work on this project, which had already generated two publications. Overall, during the course of this project, the team achieved the following:

- Synthesised in vitro (via a cell-free wheat-germ system in membrane mimicking environments of micelles, liposomes and nanodiscs) a large membrane anion efflux transporter HvBot1;
- Defined chemical environments, in which HvBot1 forms mono-and tri-meric assemblies. These forms are in a dynamic equilibrium in plant plasma membranes;
- Showed that HvBot1 transports borate and other negatively charged inorganic anions (phosphate, nitrate, chloride) using stopped-flow light scattering spectroscopy;
- Discovered that in vitro HvBot1 operates as a channel and is Na+-dependent, using planar lipid-bilayers;
- Demonstrated by Small Angle X-ray Scattering that HvBot1 spans a lipid bilayer and that upon HvBot1 incorporation in liposomes, the thickness of a lipid bilayer is lowered.
- Showed unique morphological properties of HvBot1 co-translationally inserted in a variety of liposomes via Atomic Force Microscopy imaging;
- Constructed in silico a three-dimensional model of HvBot1 using molecular modelling and molecular dynamics simulations; this effort provided the first unprecedented view of the HvBot1 monomeric and oligomeric structural assembly;
- Allocated in silico that Na+-binding site (clasp) of HvBot1 is confined to the environment of six amino acid residues of cytoplasmic loops;
- Constructed a library of variants of HvBot1, mutated in a Na+ binding clasp, and measured transport properties in vitro;
- Constructed in silico a library of variants of HvBot1 and reconciled structural properties with permeation function.

Outputs and outcomes

Two new publication outputs have arisen from this project, with two manuscripts to be submitted by mid-2015:

1. Nagarajan Y, Rongala J, Luang S, Shadiac N, Hayes J, Sutton T, Gilliham M, Tyerman SD, McPhee G, Voelcker NH, Mertens HDT, Kirby N, Singh, A, Lee J-G, Yingling YG, Hrmova M (2015) Molecular function of a plant anion-permeable efflux transporterinvolved in boron toxicity tolerance.
   To be submitted to the Nature Publishing Group
2. Zieleniecki JL, Nagarajan Y, Rongala J, Waters S, Hrmova M, Köper I (2015) Functional incorporation of a transmembrane transporter into a tethered bilayer lipid membrane using wheat germ cell-free synthesis.
   To be submitted to the Journal of American Chemical Society

ACIAR's John Dillon Fellows with Dr Battina Berger at The Plant Accelerator®.

2 Enhancing the reputation of the Waite as 'world-leading'

2.1 Communications and media

In 2014, the WRI's only funded activity in the area of communications and media was Harvest, a weekly community radio program which first went to air in August 2013.

Harvest on Radio Adelaide

Harvest is about the 'science you can eat'. The program features Waite researchers interviewed on selected themes, off-beat country music and general-interest and topical agriculture stories. *Harvest* was the sixth most popular (of 88 shows) on Radio Adelaide in 2014, and generated significant online content for the WRI and wider Waite. As well as reaching an average estimated listening audience of 20,000 per week, there were 1899 unique visits (via the Radio Adelaide site) to the *Harvest* web page in 2014 and an estimated total of 8149 online views for the year. Content generated by Harvest was also shared via the Waite partner organisations, extending its reach.

The program has also been an effective training ground for early career researchers, including several graduates of the WRI's Research Leadership Development Program, who were making their first forays into media.

The hour-long program was broadcast on Wednesday afternoons throughout 2014 and podcasts of interviews from the program can be heard online at **www.radio.adelaide.edu.au/harvest.**

Waite Communicators Group

The WRI continues to be an active leader and participant in the Waite Communicators Group, comprising media, communications and marketing personnel from all the Waite partner organisations. Members of this Group have also contributed significantly to improvements during the last few years in the quality and flow of information between the organisations at the Waite. With shared and overlapping interests in events, media liaison, high-profile visitors to the Campus, publications and display materials, the Group has made progress in the linking of various websites and the consistency of online content, as well as developing ideas for shared resourcing of activities.

2.2 Events

Debate@The Waite

The Debate@The Waite is a highly successful public event series, run by the WRI since 2011, which aims to engage the broader community in agricultural issues in an informative, interactive and entertaining way. The debate format provides an ideal vehicle for engagement because many agricultural issues are complex and involve both scientific and social aspects. The debates are based on traditional Oxford rules, consisting of two teams that argue for or against a proposition with the audience voting to decide the winning team.

The Debate@The Waite series continued in 2014, with two debates held on the following topics:

- Agriculture contributes more to society than medicine (March)
- The GM debate should only be about the science (October)

The Debate@The Waite series has proven to be an effective vehicle for enhancing collegiality and cross-disciplinary networking, with speakers from a range of Faculties and Disciplines featuring alongside Waite and private sector speakers.

Audiences in 2014 averaged 100 per event, with a large proportion from the general public. The Debates are run in collaboration with the RiAus and achieve greater dissemination through real-time Twitter, live-streaming and podcast posting on the WRI website. The two debates from this year were also broadcast as hour-long specials on Radio Adelaide's Public Domain program.

2.3 Awards and Honours

Professor Mike McLaughlin was made a Member (AM) of the Ordinary Division of the Order of Australia, in recognition of significant service to conservation and the environment, particularly through developing public policy on science-based strategies for minimising metals in the environment.

2.4 Campus tours and visits

Given the large number of organisations, centres and facilities on the Waite site, and the critical mass in plant science, wine, natural resource management and agricultural research they represent, the Waite receives hundreds of visitors each year, from secondary school students to prominent politicians, international researchers and business leaders.

The WRI continued to provide a 'front door' service to the Waite Campus in 2014, planning and hosting many tours of the Campus' joint facilities in collaboration with the Waite partner institutions. This activity supports the development of new collaborative relationships with national and international institutions.

During 2014, the WRI hosted, facilitated and/or coordinated the Waite visits of the following visitors/groups:

- Professor Peter Holmstedt, Research Institutes Sweden
- ACIAR John Dillon Fellows
- Site visit and wine tasting for the UA Invitational Alumni Golf Tournament
- European Union Economic and Commercial Counsellors
- Peter MacLeod and Richard Dickman, Bayer Crop Science
- A North Carolina State University delegation
- A group of 21 African Trade Officials
- A Fertilisers Australia conference site visit
- A number of Shanghai Jiao Tong University visitors
- A group of 25 TAFE Horticulture students
- A group of Japanese exchange students from Glenunga International High School

3 Increasing collaboration across the Waite

The WRI continued to play a key role in increasing and enhancing collaboration at the Waite Campus during 2014 by:

- providing a central coordination and communication point for the Waite partner organisations on potentially developing joint initiatives, applications and other responses to external opportunities;
- stimulating collaborative activity and proposals by supporting internal competitive, merit-based funding opportunities for joint projects and shared equipment purchases;
- facilitating and supporting the Waite Strategic Leadership Group and the Waite Communicators Group;
- facilitating, sponsoring and organising a range of activities that are of mutual benefit to the Waite partners or which build trust, communication, a collegiate atmosphere and shared interests. These include the Harvest radio program, Debate@The Waite, Peter Waite Day and the Research Leadership Development Program.

3.1 Shared investment, infrastructure and activities with Waite partners

One of the major benefits arising from the unique co-location of several complementary R&D organisations at the Waite is the ability to share resources and co-invest in infrastructure, people and technology to mutual benefit with reduced cost and duplication.

The WRI's 2013 investment in shared Waite platform technologies and infrastructure was designed to significantly enhance and complete existing projects and build collaboration on the Campus. The use of Waite facilities such as Adelaide Microscopy, Waite Analytical Services, Australian Genome Research Facility (AGRF), Metabolomics Australia, the Plant Accelerator or MiSeq Next-Gen sequencing was mandatory in applications for that funding round. Activity on these projects continued throughout 2014.

The WRI's equipment round in late 2013 elicited joint applications from across the Waite partner organisations, with nearly $100K allocated to purchases of microscopes and other specialist equipment that is being well utilised by multiple groups.

In 2014, the WRI provided assistance and support in organising Waite facilities tours for staff and students across the Campus, to facilitate awareness of other areas' research capability and availability of services as well as stimulating potential networking and collaboration.

3.2 Waite Strategic Leadership Group

The Waite Strategic Leadership Group is a consultative and advisory group comprised of the leaders of the Waite organisations. It aims to foster communication about and develop a shared strategic direction for collaborative research activities at the Waite Campus. The Group's goal is to identify emerging opportunities and ensure that the Waite organisations are working together to deliver on them, whilst building capacity for step improvements in Australian agriculture.

The WRI continues to facilitate and support the activities of the Waite Strategic Leadership Group through the provision of secretariat and support services. The WRI also coordinates and hosts regular site visits incorporating the Waite partner institutions' facilities and personnel.

3.3 Peter Waite Day - Building the Campus Community

Peter Waite Day is an informal campus community-building exercise held to coincide with the anniversary of Peter Waite's birthday, 9 May each year. Held at the Lirra Lirra Café and adjacent McLeod House lawns, the event features a strongly-contested Bocce tournament between staff from across the Waite Campus organisations.

Peter Waite's generous bequest to The University of Adelaide for the purpose of agricultural research and education and the legacy of his foresight embodied in the Waite Campus today are celebrated and remembered on this occasion each year; the 2014 event saw The Plant Accelerator team win the Bocce tournament to collect the Peter Waite Trophy.

4 Developing Waite people for the future

4.1 Targeted Support of Early to Mid-Career Researchers

In 2014, the third cohort of 10 early-mid career Waite researchers completed the WRI's highly successful Research Leadership Development Program. Developed by the WRI in conjunction with executive coach Karilyn Fazio of the Impetus Team and tailored especially for agricultural research scientists working in a University environment, the program consisted of a two-day workshop, a Dragons' Den pitching session and personal and small group coaching to help participants identify their own personal 'brand', overcome obstacles and self-sabotaging behaviours and harness their full potential. Group 3 included two participants from AFW, three from SARDI, four from ACPFG and one from the APPF and feedback indicated how valuable this cohort found the networking and relationship building that occurred during the program, particularly with peers from other organisations and centres.

Analysis of the number of AFW grant income and publications in 2014 shows a significant increase in the number of both, with the graduates of the WRI's Research Leadership Development Program prominently featured. The School of AFW and the Waite more broadly are now reaping the rewards of investment in the younger generation of researchers.

Some of the developments in 2014 for graduates of the RLDP include:

- **Kerry Wilkinson, Cassandra Collins, David Jeffery and Paul Grbin** led the development of online and interactive material in a cross-section of introductory viticulture, oenology and sensory topics for a free wine education MOOC (Massive Open Online Course), one of the first two to be established using The University of Adelaide's EdX platform. The course accrued in excess of 19,000 enrolments globally, and will be running again late in 2015.
- **Matthew Gilliham** was instrumental in a successful bid for seven years further funding of the Centre of Excellence for Plant Energy Biology from the Australian Research Council; $750,000 per annum is allocated to the Adelaide node. Additional contributions from the University and the state government bring the total funding for the node to more than $1 million per annum.
- **Matthew Tucker** commenced his ARC Future Fellowship working in the ARC Centre of Excellence in Plant Cell Walls on plant cell differentiation and plasticity.
- **Tim Sutton** was the senior/corresponding author on a paper published in *Nature* (Pallotta, et al 2014) reporting on the team's discovery of the molecular genetics of boron tolerance in wheat. He commenced a new role - Principal Scientist, Crop Improvement with SARDI - at the end of November, and remains in the WRI as an affiliate staff member.

WRI and the Waite partnerships

The Waite Research Institute keeps alive the vision of Peter Waite by supporting the collective interests of the Waite Campus organisations. We do this by facilitating collaborative activity and communications, sponsoring and organising campus-community building exercises like Peter Waite Day and supporting collaborative initiatives such as conferences and workshops that bring the Waite organisations together or bring other scientists from the national and international arena to the Waite.

The Waite partnerships are an integral and valuable part of the Campus and its collegiate culture.

The WRI facilitates strategic partnerships on the Waite Campus.

The School of Agriculture, Food & Wine

THE UNIVERSITY of ADELAIDE

(AFW), one of five Schools within the Faculty of Sciences at The University of Adelaide, is a world-class concentration of scientific research, education and product-conferring capability, the centrepiece of the Southern Hemisphere's largest collection of expertise in plant genomics, crop improvement, sustainable agriculture, animal science, dry land farming, horticulture, viticulture, oenology, wine business and food and health. The School currently comprises 50 tenured academic staff, 108 contract academic and research staff, 165 research postgraduate students, 130 coursework postgraduate students, 700 undergraduates, and 380 externally registered students.

The School is organised into the following research themes:

- Farming Systems
- Food & Nutrition
- Plant Breeding & Genetics
- Plant Protection
- Plant Physiology, Viticulture & Horticulture
- Soil Science
- Wine Science

The School of Agriculture, Food and Wine is involved in a number of specialist research centres and entities:

FOODplus RESEARCH CENTRE

FOODplus Research Centre

www.adelaide.edu.au/foodplus

LOCATION: Waite Main Building, Waite Road, Waite Campus, Urrbrae

FOODplus, a unit within the School of Agriculture, Food and Wine and joint venture of the Women's and Children's Health Research Institute and the University of Adelaide, develops research sustainability in food and nutrition as it relates to human health. It plays a key role in setting the national agenda in relation to Food and Nutrition. FOODplus identifies agricultural products that subscribe to the FOODplus mission and develop opportunities to leverage those products. Research focuses on translating nutrition research into food products with health outcomes and economic relationships with industry and coal-face agriculture.

ACPFG
AUSTRALIAN CENTRE FOR PLANT FUNCTIONAL GENOMICS PTY LTD

Australian Centre for Plant Functional Genomics (ACPFG)

www.acpfg.com.au

LOCATION: Plant Genomics Centre, Hartley Grove, Waite Campus, Urrbrae

The Australian Centre for Plant Functional Genomics (ACPFG), a unit within the University of Adelaide and its School of Agriculture, Food and Wine, is one of the largest cereal crop genomics facilities in the southern hemisphere, employing more than 150 research scientists and staff, with research nodes at The University of Adelaide, The University of Melbourne, The University of Queensland, and The University of South Australia. ACPFG is a joint investment by the Australian Research Council, Grains Research and Development Corporation, South Australian Government and University of Adelaide.

Plant Cell Walls
ARC Centre of Excellence

ARC Centre of Excellence in Plant Cell Walls (PCW)

http://www.plantcellwalls.org.au

LOCATION: Level 4, WIC Building, cnr Paratoo Road and Hartley Grove, Waite Campus, Urrbrae

The ARC CoE PCW commenced as a 7 year $32million collaboration between the Universities of Adelaide, Melbourne and Queensland in partnership with SA State Government and seven international institutions in 2011. It is hosted by the University of Adelaide at its Waite Campus.

Australian Plant Phenomics Facility

Australian Plant Phenomics Facility (APPF) - The Plant Accelerator

www.plantphenomics.org.au

LOCATION: The Plant Accelerator, Hartley Grove, Waite Campus, Urrbrae

The Plant Accelerator, a national facility established under the Commonwealth National Collaborative Research Infrastructure Scheme (NCRIS), is a world-leading plant phenomics facility The APPF is a national research facility established in 2009 under the Commonwealth National Collaborative Research Infrastructure Strategy (NCRIS). The Facility has two nodes; The Plant Accelerator at the Waite Campus and the High Resolution Plant Phenomics Centre located at CSIRO Plant Industry and the Australian National University in Canberra.

The Plant Accelerator offers state-of-the-art plant growth environments and high-throughput phenotyping (HTP) platforms which increase the speed and scale of plant physiological measurements, and help address the phenotyping bottleneck that is restricting the flow-through of genomics advances into improvements in crop performance. Carrying out projects with large populations of plants enables genetic studies to be undertaken to identify the molecular basis of complex physiological traits. Phenomics also provides a better understanding of how environmental components, both natural and artificial, affect plant growth and performance.

ARC Centre of Excellence in Plant Energy Biology (Adelaide node)

The University of Adelaide became a node of the ARC Centre of Excellence in Plant Energy Biology (PEB) in 2011, with Professor Steve Tyerman becoming a Chief Investigator in the Centre in July of that year.

The Centre comprises The University of Western Australia, Australian National University and The University of Adelaide, seven Chief Investigators and over 110 internationally competitive staff and students. It is funded primarily through the Australian Research Council ($12.5 million (2005) + $9.8 million (2011-2013)) and $13.7 million from the partner universities to fund the Centre through to 2013.

The research focus of the Centre on the metabolic reactions that allow plants to use energy from the sun to produce the oxygen we breathe, the food we eat and remove waste carbon dioxide from the atmosphere. The long-term goal is to comprehend this system well enough to not only understand how plants function at a cellular level, but to be able to design optimal energy metabolism for particular functions (for example, starch, sugar or biofuel production), or in response to harsh environmental conditions.

wineinnovationcluster.com
Synergy in grape & wine research

The Wine Innovation Cluster

www.wineinnovationcluster.com

LOCATION: Wine Innovation Central Building, Cnr Hartley Grove and Paratoo Road, Waite Campus, Urrbrae

The WIC is a virtual entity and partnership of four leading Australian grape and wine research agencies. Based on the Waite Campus, the WIC strives to build collaboration and create synergies in research and development across the co-located partner organisations for the benefit of Australia's multi-billion dollar wine industry.

The WIC represents critical mass in terms of national wine R&D capability; a 2012 audit showed that just over 60 per cent of the total is located at the Waite Campus and incorporated in the WIC. The WIC was established in recognition of the fact that enhanced coordination and integration of R&D is necessary to build the quality outcomes and effective delivery needed by the wine and grape growing industries to meet the challenges of the future.

Collectively, the WIC partners cover the entire grape and wine research, development and extension spectrum and the WIC is continuously exploring opportunities for collaborative research projects. Since it was established in 2008, the WIC partners have worked on more than 35 collaborative projects that have attracted $25m+ external funding; strong industry partnerships on many of them attest to their relevance.

Co-location partners

The Waite Campus is unique in the number of research partners located on it. These partners include Federal and State government agencies as well as national research centres and industry-funded organisations such as the Australian Wine Research Institute. Some partners have been on the campus for many decades but, irrespective of their period of residency, all have added greatly to the richness of the research environment. They have invested in buildings and other infrastructure and have formed effective collaborative relationships with each other. The Wine Innovation Cluster is a recent example of the latter but there are also numerous bilateral links. The co-location model that epitomises the Waite Campus is wideley admired and has helped maintain the reputation of the campus, and therefore the University, as the leading academic agricultural research institution in Australia.

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

www.csiro.au

LOCATION: Prescott, Taylor, Cornish and WIC West buildings, Waite Campus, Urrbrae

CSIRO, the national research provider, maintains a presence at the Waite which for most of 2014 was comprised of parts of the Agriculture and Land & Water Flagships.

CSIRO conducts agricultural research to help improve the profitability and sustainability of Australian farms and works to improve the quality and yield of Australian grain, horticultural and fibre crops aimed at improving Australia's food production and farming systems to ensure food and fibre are delivered to Australians on a sustainable basis. CSIRO's Waite-based research is also focussed on science and policy to underpin sustainable management of Australia's natural resources (soil, surface and groundwaters).

Government of South Australia
Primary Industries and Resources SA

SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

South Australian Research and Development Institute (SARDI)

www.pir.sa.gov.au/research

LOCATION: : Plant Research Centre, 2b Hartley Grove, Waite Campus, Urrbrae

SARDI, a Division of the South Australian Department of Primary Industries and Regions (PIRSA), is the SA Government's principal research institute for primary industries creating opportunities to ensure the agriculture, food, aquatic and bioscience industries are internationally competitive and ecologically sustainable. SARDI focusses on food safety and innovation, production systems and productivity enhancement, water utilisation and climate adaptation, product integrity, plant breeding, molecular diagnostics, market access, supplier competitiveness and biosecurity. SARDI research divisions are aquatic sciences, livestock and farming systems, and sustainable systems. SARDI has 339 scientific, technical and support staff and has management responsibility for 12 research centres across South Australia.

The Australian Wine Research Institute

Australian Wine Research Institute (AWRI)

www.awri.com.au

LOCATION: Levels 2 & 3, Wine Innovation Central Building, cnr Paratoo Road & Hartley Grove, Waite Campus, Urrbrae

The Australian Wine Research Institute, incorporated in 1955, has contributed substantially to the success of the Australian wine sector since then, striving to deliver value to Australian grape and wine producers with world-class research and development, as well as integrated information and knowledge extension, education and commercial services activities. Priorities for research, development, extension and commercial services are driven by the Australian grape and wine sector. AWRI's staff aim for fundamental understanding and direct industry application and are specialists in traditional and cutting edge disciplines such as: winemaking, sensory science, organic and analytical chemistry, chemical engineering and life cycle analysis, mass spectrometry and spectroscopy, bioinformatics and chemometrics, biochemistry, molecular biology, metabolomics and systems biology, microbiology, fermentation management, and knowledge and information management.

AGT

Australian Grain Technologies Pty Ltd (AGT)

www.ausgraintech.com

LOCATION: Office GE09, Main Building, Waite Road, Waite Campus, Urrbrae

Australian Grain Technologies Pty Ltd (AGT) is Australia's largest wheat breeding company. AGT was established in June 2002 as part of a national initiative to re-focus and re-position Australia's wheat breeding efforts in a rapidly changing, highly competitive, global economy. The original shareholders of AGT were the Grains Research and Development Corporation (GRDC), the South Australian Research and Development Institute (SARDI), and the University Adelaide (UA). AGT began by consolidating more than 100 years of wheat breeding activities formerly managed by UA at both the Waite and Roseworthy Campuses with those undertaken by the Victoria Department of Agriculture at Horsham. These south-eastern Australia focussed programs have dominated the total area sown to wheat in Australia for more than 30 years. AGT currently manages four significant regionally based wheat breeding operations at Northam in Western Australia, Narrabri in New South Wales, Wagga Wagga in New South Wales and Roseworthy in South Australia.

AGTs success depends on its ability to meet the current and future needs of the Australian grains industry and the demands of growers and their markets. With comprehensive wheat breeding operations based in each of Australia's four major wheat production zones, it is a national enterprise based at the Roseworthy and Waite campuses.

AGT is an independent company with governance oversight by a Board.

agrf Australian Genome Research Facility Ltd

Australian Genome Research Facility (AGRF)

www.agrf.org.au

LOCATION: Plant Genomics Centre, Hartley Grove, Waite Campus

AGRF, a not for profit incorporated company established under the Commonwealth Major National Research Facility (NMRF) Program, is Australia's largest provider of genomics services and solutions. AGRF has laboratories in Brisbane, Sydney, Melbourne and Adelaide. The Adelaide node is the national centre servicing the agriculture and related industries provides a full range of applied genomics, array fabrication, bioinformatics, epigenomics and structural genomics, gene expression, genotyping, nucleic acid extraction, plant growth and stress, research and technology, sequencing and next generation sequencing services and long term storage.

arris agricultural & environmental | arris marketing communications | arris water treatment & technology

Arris Pty Ltd

www.arris.com.au

LOCATION: Hartley Grove, Waite Campus, Urrbrae

Arris is an innovative Australian-owned consulting and communications company, providing services in two distinct areas: agricultural & environmental services, and marketing/communications. The Arris team has a unique mix of qualifications and experience in science, agriculture, communications, event management, education and training, graphic design, web design and computer technologies and provides services for a diverse range of clients.

The WRI and the Waite's Future

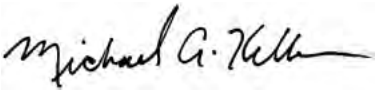
Message from the incoming Director

At the start of 2015, I was appointed as Director of the Waite Research Institute, in addition to my appointment as Dean of the Waite and Head of the School of Agriculture, Food & Wine. During my 28-year tenure at the Waite, I have seen an incredible range of scientific discoveries, taught and mentored many students, and engaged in research on various insect problems. It is truly a privilege to serve as Director of this Institute, which has now celebrated its fifth anniversary and laid some excellent foundations for the Waite to build on. As we look to the future, the WRI will continue its mission to foster excellent research, develop research talent, and invest in strategic partnerships and activities that sow the seeds for greater research initiatives and greater scientific capability.

In 2015, the Waite Research Institute will support projects that cultivate strategic international partnerships. These include North Carolina State University, the University of Nottingham, and Shanghai Jiao Tong University. Each of these partners shares common interests with the Waite and has complementary academic expertise and facilities. We aim to capitalise on the potential of these partnerships though joint research and academic exchanges that ultimately deliver high-impact scientific research in Agriculture, Food and Wine.

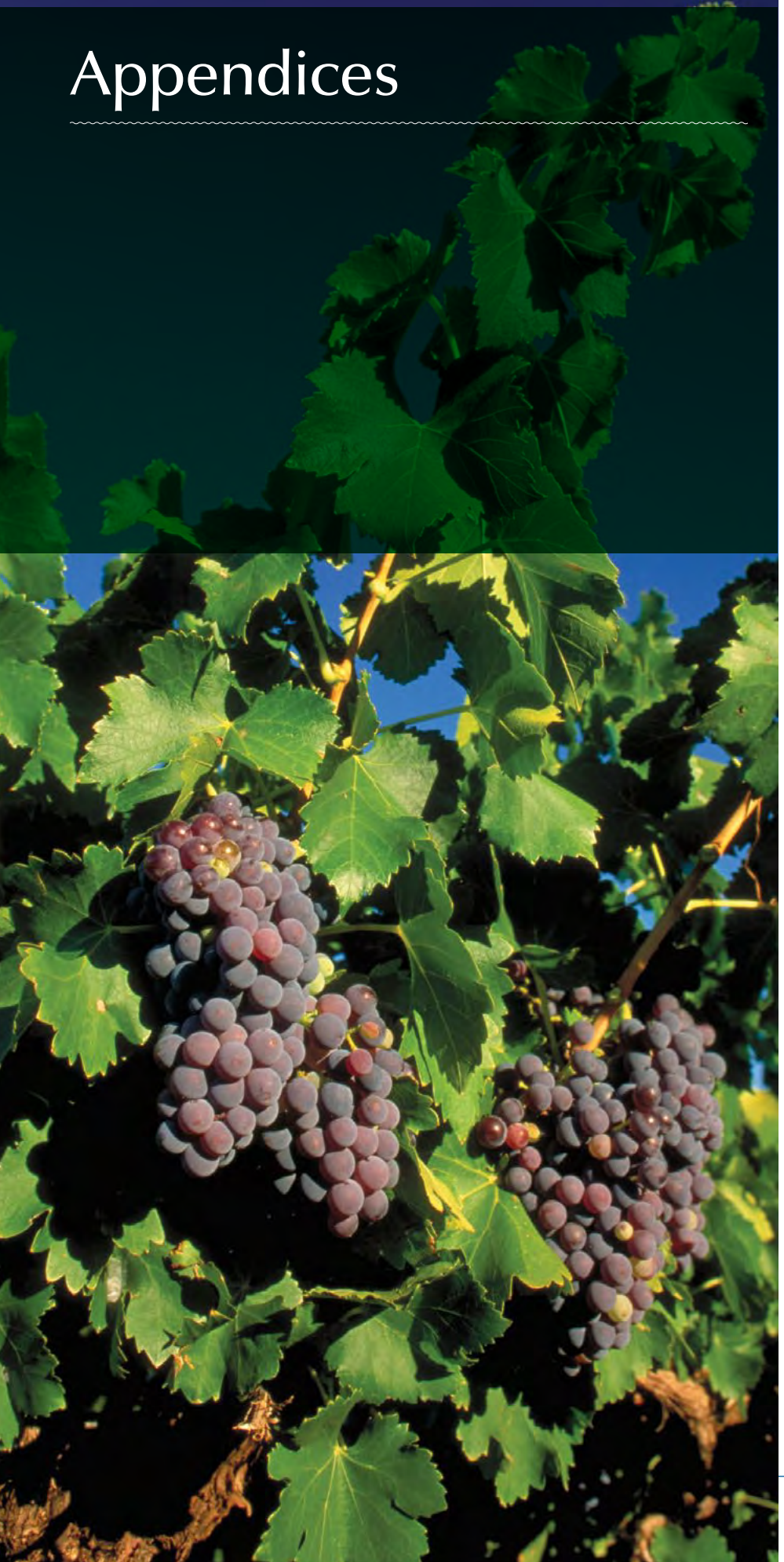
As a prime example, in January 2015, we welcomed Professor Dabing Zhang and the establishment of his laboratory, the University of Adelaide- Shanghai Jiao Tong University Joint Laboratory for Plant Science and Breeding. Professor Zhang now holds a half-time appointment, and will spend six months of each year at the Waite. His research focuses largely on cereal reproduction. Professor Zhang and his group are substantially supported by the Waite Research Institute.

I would like to thank the past Director, Professor Mike Wilkinson for his leadership and vision, which have served the Institute well.



Professor Michael Keller

J.A.T. Mortlock Professor of Plant Protection



Appendices

Appendix 1

WRI Members

(Active AFW researchers in 2014)

Able, Amanda	Donato, Adaweyah
Able, Jason	Doolette, Ashlea
Asenstorfer, Robert	Drew, Damien
Baldock, Jeffrey	Dry, Peter
Bastian, Susan	Dundas, Ian
Baumann, Ute	Eagles, Howard
Berger, Bettina	Eales, Kathryn
Betts, Natalie	Eckermann, Paul
Bianco-Miotto, Tina	Eglinton, Jason
Borysyuk, Nikolai	Eliby, Serik
Boutsalis, Peter	Facelli, Evelina
Breen, Jimmy	Fincher, Geoffrey
Buhl, Jerome	Fleet, Benjamin
Burton, Rachel	Fleury, Delphine
Byrt, Caitlin	Ford, Caroline
Cargill, Margaret	Ford, Christopher
Cavagnaro, Timothy	Fox, Rebecca
Chalmers, Kenneth	Franco Garcia, Alex
Clarke, Stephen	Garcia, Melissa
Coleman, Desmond	Gardner, Jennifer
Collins, Cassandra	Garnett, Trevor
Collins, Helen	Genc, Yusuf
Collins, Nicholas	Gibson, Robert
Coqui da Silva, Rodrigo	Gill, Gurjeet
Coventry, David	Gilliham, Matthew
Coventry, Stewart	Glatz, Richard
Cozzolino, Daniel	Gogel, Beverley
Croxford, Adam	Grant, Cameron
Cu, Suong	Grbin, Paul
Culbert, Julie	Habili, Nuredin
Davies, Kerrie	Haefele, Stephan
De Bei, Roberta	Hanold, Dagmar
Dechorgnat, Julie	Hayes, Julie
Degner, Sophia	Henschke, Paul
Degryse, Fien	Herderich, Markus
Delaporte, Kate	Heuer, Sigrid
Denton, Matthew	Hogendoorn, Katja

Hrmova, Maria
Hsieh, Yves
Huang, Chunyuan
Hussain, Syed
Islam, AKM Rafiqui
Ismagul, Ainur
Ismail, Ismail Ahmed
Jacobs, Andrew
Jefferies, Stephen
Jeffery, David
Jenner, Colin
Jha, Deepa
Jiranek, Vladimir
Kaiser, Brent
Keller, Michael
Khoo, Kelvin
Kleemann, Samuel
Koltunow, Anna
Kookana, Rai
Koopman, Darren
Kovalchuk, Nataliya
Kravchuk, Olena
Kuchel, Haydn
Langridge, Peter
Langridge-Reimold, Ursula
Leigh, Roger
Lewis, Rob
Li, Yongle
Liccioli, Tommaso
Little, Alan
Longbottom, Mardi
Lopato, Sergiy
Loveys, Beth
Luang, Jeab
Lyons, Graham
Malone, Jenna
March, Timothy
Mares, Daryl
Marschner, Petra
Mason, Sean
Mather, Diane
Mayo, Gwenda
McBeath, Therese
McDonald, Glenn
McLaren, Tim
McLaughlin, Michael
McNeill, Ann
Melino, Vanessa
Mrva, Kolumbina
Muhlack, Richard
Muhlhausler, Beverly
Niimi, Jun
Nuberg, Ian
Okada, Takashi
Okamoto, Mamoru
Oldach, Klaus
Ovchinnikova, Evgenia
Paull, Jeffrey
Pearson, Allison
Penfold, Chris
Petrie, Paul Robert
Petrovic, Tijana
Plett, Darren
Preston, Christopher
Ramesh, Sunita
Randles, John
Rengasamy, Pichu
Riggs, Karina
Ristic, Renata
Rodriguez Lopez, Carlos
Roy, Stuart
Rutley, David
Sadras, Victor
Schultz, Carolyn
Schwerdt, Julian
Scott, Eileen
Shahinnia, Fahimeh
Shelden, Megan
Shi, Bu-jun
Shirley, Neil
Singh, Rohan
Skouroumounis, George
Smernik, Ronald
Smith, Andrew
Smith, Sally
Sornaraj, Pradeep
Sosnowski, Mark
Stockley, Creina
Suchecki, Radoslaw
Sumby, Krista
Sundstrom, Joanna
Sutton, Timothy
Sweetman, Crystal
Tate, Max
Taylor, Dennis
Taylor, Julian
Tilbrook, Joanna Charlotte
Timmins, Andy
Tiong, Jingwen
Topping, David
Tricker, Penny
Tucker, Matthew
Tyerman, Stephen
Unkovich, Murray
Vandeleur, Rebecca
Vassos, Elysia
Verbyla, Arunas
Walker, Michelle
Walker, Robert
Wallwork, Hugh
Watson-Haigh, Nathan
White, Thomas
Whitford, Ryan
Wilkinson, Kerry
Wilkinson, Mike
Wirthensohn, Michelle
Xu, Bo
Yang, Nannan
Zhou, Jo
Zhou, Yi
Zhu, Ying
Zwer, Pamela

Appendix 2

2014 Financial Statements

Expenditure

	2014 Actual
	$
Growing the quality of Waite science	389,684
Enhancing the Waite's reputation	55,312
Enhancing Waite collaboration	28,248
Developing Waite people for the future	18,900
	492,144
Staffing & Office Administration	220,409
2014 Net Operating Expenditure	**$712,553**

Income (to the School of AFW)

	2014 Actual
	$
Category 1	20,725,453
Category 2	2,423,821
Category 3	11,804,588
Category 4	-
Total Research Income	**34,953,863**

Appendix 3

2014 Publications

To view or download the full list of AFW publications from the 2014 calendar year go to www.adelaide.edu.au/wri/2014_publications

Book Chapters 17

Journal Articles 390

Conference Proceedings 34

Patent 1

Appendix 4

List of Relevant Acronyms

ACPFG	Australian Centre for Plant Functional Genomics
AFW	The University of Adelaide's School of Agriculture, Food & Wine
AGRF	Australian Genome Research Facility
AGT	Australian Grain Technologies
ARC	Australian Research Council
APPF	Australian Plant Phenomics Facility (The Plant Accelerator)
AWRI	Australian Wine Research Institute
CSIRO	Commonwealth Scientific & Industrial Research Organisation
DENR	Department of Environment & Natural Resources
EIF	Education Investment Fund
GRDC	Grains Research & Development Corporation
GWRDC	Grape and Wine Research and Development Corporation
HAL	Horticulture Australia Limited
LIEF Funding	Large Infrastructure & Equipment
PCW	ARC Centre of Excellence in Plant Cell Walls
PEB	ARC Centre of Excellence in Plant Energy Biology
PIRSA	Department of Primary Industries & Regions South Australia
PISC	Primary Industries Standing Committee
RIRDC	Rural Industries Research and Development Corporation
SARDI	South Australian Research & Development Institute
UA	The University of Adelaide
WIC	Wine Innovation Cluster
WRI	Waite Research Institute

For further enquiries

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SOUTH AUSTRALIA