



THE UNIVERSITY OF
**WESTERN
AUSTRALIA**

Institute of Agriculture

Annual Research Report

2017

Sustaining productive
agriculture for a
growing world



Vision

To provide research-based solutions to food and nutritional security, environmental sustainability and agribusiness.

Mission

To enhance The University of Western Australia's contribution to the advancement of agriculture and to the management of natural resources in selected international, national and regional settings.

For Western Australia, the Institute works with the agricultural and natural resource management sectors to create knowledge and improve workforce skills, such that those committed to agriculture may advance their individual aspirations, contribute to local and regional prosperity and exercise responsible stewardship of the environment.

Strategies

Integration: Bringing together the University's agricultural research and communication activities; integrating complementary activities across disciplines and organisational units, and providing a focus for leading-edge research, development, extension and adoption (RDE&A).

Communication: Strengthening communication links with regional industry, farmer groups and the broader regional and scientific communities.

Connecting: Fostering national and international linkages and alliances that bring new knowledge and expertise to Western Australia, and allow Western Australia to share its knowledge with the world.

Resourcing: Increasing the pool of resources available for investment in critical RDE&A in Western Australia and in relevant national and international issues.

Front Cover Image: Mary Murphy

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Director's overview

On behalf of The University of Western Australia, I am pleased to present the 2017 Annual Research Report for The UWA Institute of Agriculture.

In 2017 we welcomed Professor Dawn Freshwater who took over from Professor Paul Johnson as Vice Chancellor of UWA. Previously the Senior Deputy Vice Chancellor, Professor Freshwater led the university through a transformation strategy and restructure, to ensure it runs efficiently towards the goal of being a top 50 university by 2050. She has a strong, clear vision to ensure the University makes a positive impact on as many people as possible.

In the new structure, there are four faculties – the Faculty of Science, Faculty of Health and Medical Sciences, Faculty of Arts, Business and Law, and the Faculty of Engineering and Mathematical Sciences. The UWA Institute of Agriculture (IOA) continued to collaborate across the four faculties, especially the new schools of Agriculture and Environment, Biological Sciences and Molecular Sciences, in the Science Faculty.

A sixth research theme, Engineering Innovations for Food Production was established in early 2017. This new theme is being co-led by Dr Andrew Guzzomi and Professor Dilusha Silva from the Faculty of Engineering and Mathematical Sciences and focuses on providing engineering solutions to agriculture for sustainable growth of net farm-yield, reduction of wastage, and minimisation of environmental impact. A recognisable and identifiable agricultural engineering theme presents extensive opportunities for collaboration between farmers and agricultural machinery manufacturers with IOA in order to undertake research and development focused on bringing about commercial innovation. Collaborative, cross-faculty, multi-disciplinary research activities continued across the five additional research themes: Crops, Roots and Rhizosphere; Sustainable Grazing Systems; Water for Food Production; Food Quality and Human Health; and Agribusiness Ecosystems.

In the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU), Agricultural Sciences at UWA jumped ten places to 14th in the world, and 1st in Australia. In previous years, agricultural sciences has been grouped with Biological Science, Human Biological Sciences, and Veterinary Sciences under the Life and Agricultural Sciences Field. This is the first year ARWU has separated the four disciplines, and we are very pleased to be recognised for our strength in national and international collaboration. I was pleased to see UWA's strong position in agriculture science is also reflected in the 2017 National Taiwan University Ranking where our ranking for *Agriculture Science* improved to 25th in the world (up from 29th in the world). This is a significant achievement made possible by committed partners, dedicated staff, challenging opportunities and strong support from the funding bodies and industry.

A major focus for 2017 was effective communication of agricultural research and training activities at UWA, and deepening our engagement with industry, farmer groups, collaborators, funding bodies and alumni. A total of 25 media statements were distributed throughout the year generating coverage in the regional and international agricultural press. Annual engagement activities such as the public lecture series, the Postgraduate Showcase and Industry Forum were well received and well-attended by our key stakeholders and the community at large.

More than 300 students from UWA and other Australian universities, international university students and academics visited UWA Farm Ridgefield in 2017. This includes approximately 80 undergraduate students who used the farm for field work as part of their studies in *Pasture and Livestock Systems*, *Clean Green and Ethical Animal Production* and *Crops and Cropping Systems*. A highlight of the year was UWA acknowledging that the farm is located on Gnaala Karla Boodja with Noongar people tracing their connections to the land back 45,000 years. This acknowledgement is an important foundation for UWA's commitment to understanding and working alongside Noongar people.



Chair's message

A massive open online course (MOOC) was launched by IOA. The course, *Discover best practice farming for a sustainable 2050* provides and overview of the four key enterprises of the Future Farm 2050 Project, sustainable agriculture in general, and UWA research. Individuals from all around the world can participate for free and in the first three months, almost 1000 people had enrolled. .

Finally, I wish to acknowledge IOA staff, associates, student Management Board members, Industry Advisory Board and Research Theme Leaders, as well as our national and international collaborators and funding bodies for their dedicated support and assistance throughout 2017.

Professor Kadambot Siddique AM, CitWA, FTSE, FAIA, FNAAS, FISPP

Hackett Professor of Agriculture Chair and Director

The UWA Institute of Agriculture
The University of Western Australia

In 2017 The University of Western Australia implemented its new strategy designed to enhance its teaching and research activities. The UWA Institute of Agriculture has a significant role to play in this new structure and I congratulate the way its staff and members continued to operate with vigour and vitality throughout the organisational change.

The IOA Industry Advisory Board has had significant engagement with the University's senior executive during 2017 and we are pleased to see a focussed approach to achieving world class status both in terms of research and education. A global recruitment strategy to appoint 50 new academics is underway, including a Professor or Professor of Practice in Dryland Farming Systems. This appointment will further strengthen UWA's position as a leader in agriculture science.

The Institute's communication activities continue to create significant discussion and interest with strong support from the agriculture industry and community. This includes translational activities involving UWA Farm Ridgefield. A key activity the Board contributes to is the annual Industry Forum. This year's forum Consolidation in agriculture: impacts to the farm, research and agribusiness was well-received by the sector.

The Department of Primary Industries and Regional Development's Dr Bruce Mullan joined IOA's Industry Advisory Board in 2017. Dr Mullan is the Director of Sheep Industry Development, and Project Manager for the Sheep Industry Business Innovation project. He represents DPIRD on a number of state and national research and development bodies, all aimed at increasing the competitiveness of the WA livestock industries. Dr Mullan has already proven to be valuable member of the Board.

I look forward to supporting the Institute to maintain strong links to the agricultural sector in the year ahead and would like to thank IOA members, members of the Board, Director, Hackett Professor Kadambot Siddique and his team, and all those who have supported IOA in its achievements to date.

Dr Terry Enright

Chair of the IOA Industry Advisory Board





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Crops, Roots and Rhizosphere

Theme leaders

Dr Louise Barton

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The Crops, Roots and Rhizosphere theme covers all aspects of crop production, both aboveground and belowground. Participants in the theme work across a broad scale from genomics and plant physiology to crop breeding and field agronomy. Projects are multidisciplinary and involve collaboration among several UWA schools and faculties, as well as with farmer groups, DPIRD, CSIRO, Curtin and Murdoch Universities, and interstate and overseas institutions. Many projects include industry partners and are designed specifically to meet their needs. Research also often involves collaboration with UWA adjuncts, who we highly value for their significant contributions to this theme. We are proud that most projects include a training component through inclusion of postgraduate students, commonly Masters by coursework project students and PhD students.

We research a broad range of crops including wheat, lupins, chickpea, field pea, canola and rice and pasture legumes. New and emerging crops are also a focus. Research is targeted both at the dryland farming systems of WA and southern Australia, as well as northern Australia and our neighbours in Asia including China, Timor Leste, Bangladesh, India and Vietnam.

UWA researchers are involved in projects focussed on topical areas including frost tolerance, crop water use efficiency, use of drones, big data and precision agriculture. UWA is fortunate to have world-class facilities, and very significant research strength, in genomics and other technologies applicable to crop breeding including accelerated single seed descent. A particular focus is root and rhizosphere biology, including root architecture, and the role of roots in stress tolerance (e.g. to waterlogging, salinity, drought, and aluminium and manganese toxicities). The means by which crop nutrient acquisition can be enhanced, particularly that of phosphorus, are also a focus with root morphological, physiological and symbiotic mechanisms all considered. Crop diseases are also researched. We also investigate the broader community of micro-organisms in the rhizosphere and their interaction with the plant. Many studies utilise our excellent Plant Growth Facilities, however, field relevance is always key and, whenever possible, research is extended to field conditions.

Overall, in this theme, we range from fundamental to highly applied agronomic research. However, at all times, we are cognisant of the needs of the industries and farmers who will ultimately apply our research outcomes to their farming systems.



Unravelling the genetic control of flowering time in narrow-leaved lupin

Project team: Ms Candy Taylor¹ (PhD candidate; candy.taylor@research.uwa.edu.au), Professor Wallace Cowling¹, Dr Matthew Nelson², Dr Lars Kamphuis^{3,4}, Dr Jens Berger³, Ms Weilu Zhang¹, Dr Gagan Garg³, Dr Karam Singh^{3,4}, Dr Federico Ribalta¹, Dr Janine Croser¹, Ms Simone Wells¹, and Ms Sabrina Tschirren¹

Collaborating organisations: ¹UWA, ²Kew Royal Botanic Gardens, UK, ³CSIRO, ⁴Curtin University, ⁵DPIRD

Owing to the recent and rapid domestication of narrow-leaved lupin, Australian and European varieties have limited genetic and phenotypic diversity for important agronomic traits, including flowering time. The majority of elite, modern cultivars are very early flowering, which adapts the crop to warm, short-season environments, such as the northern WA wheatbelt. However, to expand the lupin industry in Australia (particularly the southern WA wheatbelt and eastern states) and Europe, it will become increasingly important to diversify flowering time and other phenological traits to better adapt and match varieties to long-season environments with higher yield potential.

As little is yet known about the genetic regulation of time to flowering in narrow-leaved lupin, this project aims to: 1) discover the extent of genetic and phenotypic diversity for this trait in a panel of more than 300 accessions, including domesticated varieties and wild accessions representing the species' natural distribution within the Mediterranean Basin; and 2) better understand the genetic identity, variation, regulation and inheritance of the three currently known genes for flowering time in narrow-leaved lupin breeding programs (*Ku*, *Julius* and *efl*).

In 2017, we completed the phenotypic work to address the first aim. In the absence of vernalisation (a period of prolonged exposure to cold temperatures that promotes flowering), a range of flowering times was observed among wild narrow-leaved lupins. Earlier to intermediate flowering was most commonly found in the eastern Mediterranean, while later flowering types were typically found in the west. We are now undertaking a genome-wide association study (GWAS) to identify new genes affecting time to flowering in narrow-leaved lupin.

Genome sequence and gene expression studies have revealed interesting features of *LanFTc1*, the main gene in the Australian breeding program, originally named *Ku*. In 2017, we discovered two new variations in the DNA sequence that regulates *LanFTc1*, one of which corresponds to the *Julius* locus for early flowering utilised in European breeding programs and is functionally equivalent to *Ku*. The other causes the gene to initially be less active, resulting in a delay of roughly two weeks in flowering relative to Australian *Ku* varieties. Such variation will be extremely beneficial for diversifying flowering time in breeding programs.

Lastly, we are generating a recombinant inbred line mapping population to locate *efl*, a less widely utilised locus in the Australian breeding program. F2 progeny of a cross with *efl* are undergoing accelerated single seed descent under optimised glasshouse conditions, with three to four months per generation, and will be ready for mapping in 2018.

This research is supported by GRDC and UWA.

1: Understanding the mechanisms controlling flowering time in narrow-leaved lupin will help in selecting locally-adapted cultivars. Photo: Candy Taylor.

Crop Genomics

Project teams: Professor Dave Edwards¹ (leader; dave.edwards@uwa.edu.au), Professor Jacqueline Batley¹ (leader; jacqueline.batley@uwa.edu.au), Dr Philipp Bayer¹, Dr Kenneth Chan¹, Dr Jenny Lee¹, Dr Anita Severn Ellis¹, Ms Mahsa Mousaviderazmahalleh¹, Mr Andy Yuan¹, Mr Armin Scheben¹, Mr Habib Rijzaani¹, Mr Ricky Hu¹, Ms Clementine Merce¹, Ms Aria Dolatabadian¹, Ms Soodeh Tirnaz¹, Ms Yueqi Zhang¹, Mr Fangning Zhang¹, Ms Ting Neik¹, Mr Hua Yang¹

Collaborating organisations: ¹UWA; International Pea genome sequencing consortium, International lentil genome sequencing consortium.

The applied bioinformatics group and the Batley laboratory have contributed to international projects to sequence the pea and lentil genomes, building on expertise they previously established through sequencing the genomes of Brassica, wheat and chickpea.

These genome assemblies, together with the related annotation and diversity information, permit the association of gene variants with important agronomic traits, which can accelerate the breeding of these important crops.

We have extended our genomics research to sequence the pangenomes of important crop species. The pangenome of *Brassica oleracea* (cabbage, cauliflower, broccoli, brussels sprouts) was published in 2016 and the pangenome of bread wheat (*Triticum aestivum*) was published in 2017. These pangenome assemblies capture the gene content of the species rather than one individual and so are more applicable for genomics-based crop improvement approaches.

This research is supported by ARC and the GRDC supported by the pea genome project.

Plant Information Systems

Project team: Professor Dave Edwards¹ (leader; dave.edwards@uwa.edu.au), Dr Kenneth Chan¹, Dr Philipp Bayer¹

Collaborating organisations: ¹UWA; International wheat information system expert working group; International rice informatics consortium; International Brassica informatics consortium

With the continued exponential growth of data for crop species, from genomes to breeding studies, there is a growing urgency to be able to manage this information for integration and reuse.

Numerous crop specific databases have been developed with diverse functionality relating to their specific user group. There is a growing trend to integrate diverse data at different locations using recently developed IT approaches for database indexing and remote query.

Professor Edwards is an international leader in crop database management, contributing to the Brassica information system, co-chair of the wheat information system expert working group, and on the advisory committee for the international rice informatics consortium.

Increasing wheat yield by genomic sequencing and germplasm exchange

Project team: Professor Guijun Yan¹ (leader; guijun.yan@uwa.edu.au), Professor Dave Edwards¹, Professor Jacqui Batley¹, Dr Hui Liu¹, Dr Daniel Mullan², Professor Aimin Zhang³, Professor Yong Zhang⁴, Professor Zhanyuan Lu⁵, Professor Yong Wang⁶, Professor Haibo Wang⁷, and Dr Shancen Zhao⁸

Collaborating organisations: ¹UWA; ²InterGrain Pty Ltd; ³Chinese Academy of Sciences; ⁴Chinese Academy of Agricultural Sciences; ⁵Inner Mongolia Academy of Agriculture and Animal Husbandry Sciences; ⁶Gansu Academy of Agricultural Sciences; ⁷Hebei Academy of Agricultural and Forestry Sciences; ⁸Beijing Genomics Institute

This project is using genome sequencing technology to investigate diverse germplasm resources in Australia and China, and accelerating the breeding of improved wheat adapted for high productivity in target environments.

We selected 200 wheat lines from Australian and Chinese germplasm stock, including lines from Inner Mongolia and the Gansu area, which has a similar dryland agriculture to Australia. Some selected genotypes had superior disease resistance performances. The lines were selected based on the phenotypic data from national variety trials, which provide phenotypic information of crop cultivars/lines with standardised trial management in multiple locations.

The data were used to assess major yield components, including seed size, seed number per ear, number of ears per unit area, plant height, quality components, disease resistance, and drought and heat tolerance. They were grown in glasshouses and their DNA was extracted. After examination of the DNA quality and quantity, they were genotyped using GBS, and their sequence data were linked to a reference genome.

In 2018, genotype-phenotype associations will be analysed and trait-associated-markers in target environments identified. DNA genotyping arrays will be developed. These will incorporate the newly identified markers, published markers and available functional markers.

These markers will be converted into Kompetitive Allele Specific PCR (KASP) markers for marker validation. KASP assay is an economical option that enables a small number of markers to be used to test a large number of samples. It is especially suitable for this project's purpose of large-scale selection in wheat breeding.

Delegates from all the global partner institutions attended a workshop at Shenzhen in November 2017. The project plan and participants' roles and responsibilities were discussed.

This research is supported by Commonwealth Department of Industry, Innovation and Science.

2: These sequencers at the Beijing Genomics Institute, one of the global partners in the project, will be used for genotyping by sequencing. Photo: Hui (Helen) Liu.



Genetic Analysis of Seed Dormancy for Pre-harvest Sprouting Resistance in Wheat

Project team: Professor Guijun Yan (leader; guijun.yan@uwa.edu.au), Dr Hui Liu, Hackett Professor Kadambot Siddique, Ms Xingyi Wang

Pre-harvest sprouting (PHS) can cause severe damage to the quality and productivity of wheat, which is the major cultivated and exported grain crop in Australia. PHS refers to unharvested wheat grains germinating or sprouting on the plant in the field when they encounter rain or air-humidity close to saturation. PHS is caused by a lack of seed dormancy, which is a quantitative trait regulated by several genes and affected by environmental factors.

Some important quantitative trait loci (QTL) for PHS resistance have been consistently identified on the chromosomes 3A, 4A and 4B. To identify the specific genes for PHS resistance, near-isogenic lines (NILs) were developed using the closest markers to the QTL on 3A, 4A and 4B. An embryo-culture-based, fast-generation system was used to shorten the developing period.

In 2017, a total of 56 putative NIL pairs targeting major PHS resistance QTL on 3AL, 4AL, and 4BL, were grown until maturity in glasshouses. Several agronomic traits, including growth rate, days to anthesis, days to maturity, tiller number, plant height, grains per spike, and 1000-kernel weight, were measured. Those putative isolines were further evaluated for PHS resistance through germination of both harvested seeds and seeds on spikes. Based on the results, a manuscript 'Characterization of near-isogenic lines targeting a major QTL on 3AL for pre-harvest sprouting resistance in wheat' was prepared and submitted to the journal *Crop & Pasture Science* for review.

To identify the putative candidate genes responsible for PHS resistance, the confirmed NILs were grown in glasshouses with well-treated water and nutrition. Seeds from those NIL pairs were harvested at three time-points (15, 25, 35 days post anthesis) and immediately snap frozen in liquid nitrogen and stored in -80°C. Later, total RNA was extracted from those seeds using a TRIZOL and Plant RNase kit from QIAGEN. Quality and integrity of the extracted RNA were determined using Nanodrop, gel electrophoresis and Labchip. Qualified samples were sent to a sequencing company (BGI) for downstream analyses. The sequencing results, will be analysed to identify the candidate genes for PHS resistance.

This research is supported by School of Agriculture and Environment, and Yipti Foundation Research Awards and Grants-in-Aid

3: Wheat seedlings ready for DNA extractions. Photo: Hui (Helen) Liu.

An integrated platform for rapid genetic gain in pulse crops

Project team: Dr Janine Croser (leader; janine.croser@uwa.edu.au), Professor William Erskine, Dr Federico Ribalta, Ms Christine Munday, Dr Richard Bennett, Ms Sabrina Tschirren, Ms Simone Wells

An accelerated Single Seed Descent (aSSD) protocol for the turnover of five to seven generations per year in field pea, chickpea, lupin and lentil was previously developed in our GRDC-funded project UWA00159. This was achieved by truncating the time to flowering and seed fill by combining rapid initiation of flowering with precocious germination technology. The aSSD technology provides a platform to more than double the current generation turnover in these species.

We have now expanded the controlled environment capacity for aSSD activities at UWA. The aSSD technology has been implemented in all four Pulse Breeding Australia (PBA) pulse breeding programs. Multiple populations have been developed and delivered to the chickpea, field pea and lentil PBA programs. We overcame a range of difficulties posed by the outcrossing nature of faba bean and low pod set under controlled environment conditions. We are currently developing the first two recombinant inbred line (RIL) populations for the PBA faba bean breeding program.

Our research has refined the key parameters required to elicit early floral induction in pulses under controlled environment conditions. Far-red enriched LED lighting combined with a tightly controlled photoperiod, temperature, physical containment, nutrient and watering regime enables rapid flowering across all field flowering phenologies (early to late).

We developed a hydroponic screen for boron tolerance in field pea using immature seeds and validated it against field and pot data. Screening methods for boron tolerance in lentil and salinity tolerance in chickpea have been validated across genetically diverse material using immature versus mature seeds. These screening methods have been fully integrated within the aSSD platform.

A controlled environment screening process has been developed for identifying variability in tolerance to chilling within the chickpea germplasm. Further refinement and comparison with field data is currently underway.

This research is supported by GRDC.

4: An aSSD multi-tier shelving system.



Genetics of wild germplasm gene-pool expansion and integrated aSSD approach to enhance adaptive potential of chickpea

Project team: Dr Janine Croser¹ (leader; janine.croser@uwa.edu.au), Dr Maria Pazos-Navarro¹, Ms Simone Wells¹, Professor Doug Cook²

Collaborating organisations: ¹UWA; ²Curtin University

In 2013 a GRDC-funded effort to collect wild *Cicer* germplasm resulted in hundreds of new accessions, particularly of *Cicer reticulatum* (the wild progenitor of chickpea) and *Cicer echinospermum* (a closely related annual species). The wild accessions hold genes for key production constraints, and extensive phenotyping and genotyping efforts are underway worldwide combining expertise from the US, Canada, Ethiopia, Turkey and Australia. A world set of wild *Cicer* nested association marker (NAM) parents has been identified and forms the basis of introgression efforts to create new genetic resources in the five partner countries.

The UWA node of this larger research effort was established in 2015 as a collaboration between Curtin University and UWA.

At UWA, we have produced a complete set of 26 confirmed

NAM hybrids, grown out selected F1 hybrid material, cloned the selected F1s to produce high F2 seed numbers (up to 2000 for the selected *C. echinospermum* crosses with high sterility).

Concurrently, we have been investigating the role of light, photoperiod and temperature on the induction of early flowering in the wild material. This has led to a modified accelerated Single Seed Descent (aSSD) platform enabling the turnover of five wild *Cicer* generations per year.

We are now using the selected F2 material to begin recombinant inbred line (RIL) population development. Two RIL populations are under development using aSSD and at the F3 seed stage from the UWA NAM hybrid combinations. We expect to attain about 200 individual F6 lines from each population by the end of 2018. This material will be lodged at the Australian Grains Genebank as a resource for chickpea improvement efforts.

This research is supported by GRDC.

5: Wild *Cicer* germplasm collection growing at UWA. Photo: Maria Pazos-Navarro.



Improving P use efficiency using a large set of chickpea germplasm under low phosphorus supply

Project team: Hackett Professor Kadambot Siddique¹ (leader; kadambot.siddique@uwa.edu.au), Dr Jiayin Pang¹, Professor Hans Lambers¹, Associate Professor Megan Ryan¹, Ms Chloe Charlotte^{1,3}, Ms Hee Sun Kim¹.

Collaborating organisations: ¹UWA; ²International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India; UniLaSalle, France³

Low availability of phosphorus (P) is considered a major constraint to crop production worldwide. It has been estimated that 5.7 billion hectares of land worldwide are deficient in phosphorus. While the problem of P deficiency is currently mitigated by application of high rates of P fertiliser, this practice is inherently inefficient due to chemical immobilisation of P and agricultural runoff. Therefore, breeding crops for improved P-use efficiency, i.e. an improved yield per unit of added P fertiliser, is arguably the best long-term, environmentally-sustainable strategy.

Chickpea has become the second most important grain legume (pulse) globally, occupying 13.5 million hectares. It is the largest pulse crop in Australia, currently grown on more than 0.5 million hectares (FAOSTAT 2014). Chickpea has a narrow genetic base due to domestication.

In recent years, a unique chickpea reference set consisting of 300 genotypes from 29 countries with diverse genetic background was developed by the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) in India. The project aims to utilise this chickpea reference set to compare the genotypic variation in P-acquisition and P-utilisation efficiency.

The results show large genotypic variation in plant growth, shoot P content, physiological P-use efficiency and P-utilisation efficiency in response to low P supply. Shoot P content is strongly correlated with shoot dry weight (DW, $r = 0.86$, $P < 0.001$), root DW ($r = 0.57$, $P < 0.001$), total root length ($r = 0.74$, $P < 0.001$), root surface area ($r = 0.79$, $P < 0.001$) and rhizosphere carboxylates ($r = 0.62$, $P < 0.001$). One hundred chickpea genotypes with contrasting growth performance were selected from the reference set for detailed morphological and physiological characterisation. A two-fold difference in photosynthetic rate and a 2.5-fold difference in photosynthetic P-use efficiency were found among the 100 genotypes. A 6-fold difference in the amount of rhizosheath carboxylate was observed.

Our results also show that carboxylates mobilise manganese (Mn) from the soil, with a strong correlation found between Mn concentration in mature leaves and rhizosheath carboxylates ($r = 0.61$, $P < 0.001$). For the first time in crop plants, this finding demonstrates that leaf Mn concentration can provide vital information on below-ground functioning as a time-integrated proxy for P acquisition via carboxylate release. This provides a valuable screening tool in breeding for high P-acquisition efficiency. Further research is currently underway to identify the biochemical, anatomical and molecular basis of photosynthetic P-use efficiency in chickpea.

This research is supported by UWA.

6: Two undergraduate students, Ms Chloe Charlotte (UniLaSalle, France) and Ms Hee Sun Kim (UWA) recording growth symptoms of chickpea grown under low-P conditions. Photo: Jiayin Pang.



Spatial temperature measurement and mapping tools to assist management of frost risk at farm scale: Rapid assessment of damage in wheat after frost

Project team: Mr Steven Crimp¹ (leader; steven.crimp@csiro.au); Dr Ken Flower², Dr Nik Callow², Dr Bryan Boruff², Ms Bonny Stutsel², Ms Mary Murphy², Mr Mick Fulkner³; Ms Kirsten Barlow⁴, Dr Eileen Perry⁴, Glenn Fitzgerald⁴, Emeritus Professor Hamlyn Jones^{2,5}

Collaborating organisations: ¹CSIRO, ²UWA, ³Agrilink, ⁴Victorian Department of Economic Development, Jobs, Transport and Resources (DEDJTR), ⁵University of Dundee

Extreme weather events, such as frost, are already a significant challenge for grain producers and are predicted to increase under future climate scenarios. Recent statistics for frost related damage in Australia estimated agricultural losses at between \$120M and \$700M each year. Frosts that occur during or after ear-emergence can often result in severe stem and head damage, which can reduce grain yields and quality by up to 80 per cent, depending on location, altitude, soils and the severity of the frost.

However, other than visually assessing a crop 5-7 days after a frost, there are no tools available to determine if a frost has occurred and to map the extent of the damage it has caused. Farmers would benefit greatly if they could obtain quasi real time information about frosted wheat paddocks that are likely to have yield losses. For example, decisions on inputs or when and how much of the crop to cut for hay could then be made. Maps of frost damaged areas of the paddock would also help farmers at harvest time, as frosted areas of the paddock could be left unharvested if necessary, thereby reducing costs.

This project aims to develop methods to rapidly assess frost damage in wheat. Both proximal and remote sensing methods will be tested using ground- (or hand-held), UAV- (RPAS) or satellite-based sensors.

Glasshouse trials were conducted along with a field trial at the Department of Primary Industries and Regional Development (DPIRD) West Dale frost research site. Unfortunately, there was little frost at the field site in 2017, although useful data was still collected.

PhD student Mary Murphy assessed spectral response of Wyalkatchem and Elmore wheat varieties to chilling/frost using multi- and hyper-spectral sensors, in both the field and glasshouse/controlled environment room. A second PhD student, Bonny Stutsel, focussed on thermal imaging and temperature dynamics in the wheat crop canopy during frosts. She used a series of in-situ ArduCrop thermal sensors and a FLIR Tau 2 640 25mm thermal camera, which was fitted to a DJI M600 PRO unmanned aerial vehicle (UAV/drone) and flown after cold events. She also obtained accurate temperature measurements using a distributed temperature sensing (DTS) 'fence' which was set up through the wheat crop trials (with different times of seeding), with the fibre optic strands at 100mm intervals from the ground to the top of the canopy.

This research is supported by GRDC National Frost Initiative.

7: DJI M 600 Pro UAV with Tetracam, Sequoia and FLIR Thermal Sensors attached. Photo: Mary Murphy.

A long-term study to increase water use efficiency, grain yield and the profit of growers in the western region in a no-tillage system.

Project team: Dr Ken Flower¹ (leader; ken.flower@uwa.edu.au), Mr Neil Cordingley², Dr David Minkey², Dr Phil Ward³, Mr Shayne Micin³ and Dr Nathan Craig¹

Collaborating organisations: ¹UWA, ²Western Australian No-Tillage farmers Association (WANTFA), ³CSIRO

The trial was started in 2007 and is based at the WA College of Agriculture Cunderdin. It was initially set up to assess if maintaining high levels of crop residues could boost crop productivity, grain production and profits in no-till systems. The focus has changed slightly and now it is investigating the agronomic and economic costs and benefits of using crop residue retention, diverse rotations, minimal soil disturbance and controlled traffic (reduced compaction) tactics over time in a no-tillage system. It is also comparing the effects of full residue retention (high residue) and windrow burning (low residue).

In 2017, yields in the different rotations were significantly affected by the rainfall pattern. There was good early rain in February (97mm) and March (20mm), followed by very dry conditions with only small amounts of rain (April 1mm, May 8mm, June 8mm), with falls mostly <3mm, until 2 July when 8mm fell. Highest wheat yield occurred where a significant amount of residue was found, which was mainly when wheat was seeded in plots following a cereal crop with retained residue.

By contrast, wheat yields were significantly reduced wherever residue levels were low, especially in the rotations/treatments with tillage or where wheat was seeded into canola residue with a legume the year before. This was because the high residue plots retained soil moisture in the zone that the wheat was seeded into, which enabled crop establishment in May, whereas the soil dried out and no wheat germinated until early July in plots where there was little residue.

This research is supported by GRDC.

8: Wheat established with into heavy cereal residue.
Credit Neil Cordingley.

Managing soil-borne root disease in sub-clover pastures

Project team: Professor Martin Barbetti¹ (leader; martin.barbetti@uwa.edu.au), Dr Ming Pei You¹, Associate Professor Michael Renton¹, Dr Kelly Rensing¹, Dr Kunmei Guo¹, Dr Alan MacKay²

Collaborating organisations: ¹UWA; ²SARDI

This project demonstrated how small variations in environmental factors such as temperature, moisture, nutrition and soil type, individually and interactively, can have profound effects on the expression and severity of damping-off and root disease and the consequent level of productivity of subterranean clover forage. Soilborne root diseases, caused by a range of pathogens, particularly Phytophthora, Pythium, Aphanomyces, and Rhizoctonia, are the major limitation to productive subterranean clover (*Trifolium subterraneum*) pastures across southern Australia. Livestock producers face critical feed shortage across autumn–winter that coincides with severe attack by soilborne pathogens that markedly decreases their autumn–winter biomass production in regenerating pasture legume stands.

This project provides a solid basis for development of more relevant soilborne disease management options for livestock producers to better manage soilborne diseases in the different regions across southern Australia.

We defined, for the first time, the importance of environmental conditions on the severity of Rhizoctonia (*Rhizoctonia solani*), Pythium (*Pythium irregulare*) and Phytophthora (*Phytophthora clandestina*) damping-off and root rot and on consequent plant productivity in southern Australian subterranean clover pastures. Environmental factors tested included a range of temperature regimes, soil moisture and types, nutrition levels and clover cultivars Riverina, Seaton Park and Woogenellup. In all studies, environmental factors were the main determinants of the severity of damping-off, root disease and plant productivity.

For Rhizoctonia, damping-off was at or close to 100 per cent at the two cooler temperature regimes of the three tested, but seedlings survived at the warmest regime. Root disease decreased under higher moisture, better nutrition and under ‘heavier’ soil conditions. Findings explain the severe devastation to subterranean clover pastures observed in the presence of this pathogen when cool seasonal conditions occur across the critical autumn feed-gap period; especially under relatively drier soil conditions and in nutritionally impoverished sandy soils where there is little competition from other soil microbes.

Phytophthora also interacted significantly with temperature, moisture, soil type and cultivar; cultivar resistance, high moisture, high or medium temperature, high nutrition and sandy soil all contributed towards less pre-emergence damping-off, less tap and lateral root disease, and greater clover productivity. Subterranean clover cultivar host resistance was critical for reducing disease severity and increasing productivity even when favourable environmental conditions for severe disease occurred. For example, in the presence of Phytophthora, the most resistant cultivar, Seaton Park, performed best under a high temperature, high nutrition and high moisture combination. The less resistant cultivars Riverina and Meteora had less disease and greater productivity under low moisture conditions less favourable for this pathogen.

For Pythium, linear modelling was used to highlight and explain the high-level (4 or 5-way) significant interactions for each dependent variable (dry shoot and root weight, emergence, tap and lateral root disease index) in relation to variations in temperature, soil, moisture, nutrition and cultivar. Boosted regression trees provided support for and helped clarify the complex nature of the relationships found in linear models. All environmental variables showed at least five per cent relative influence on each of the five dependent variables. Models highlighted differences due to soil type, with the sand-based soil having either higher weights, greater emergence, or lower disease indices. The lowest weights and lowest emergence, as well as higher disease indices, were found for loam soil and low temperature. There was more severe tap and lateral root rot disease in higher moisture situations. For Pythium, this was the first study to use a comprehensive modelling approach to highlight the importance of environmental conditions, as occur across southern Australia, upon severity of damping-off and root disease and productivity.

This research is supported by MLA.

9: Typical subterranean clover pasture severely affected by root disease showing stunted and missing plants. Photo Ming Pei You.

Improved subterranean clover seed production from multiple disease resistance

Project team: Professor Martin Barbetti¹ (leader; martin.barbetti@uwa.edu.au), Dr Ming Pei You¹, Dr Phillip Nichols^{1,2}, Professor William Erskine¹, Dr Parwinder Kaur¹

Collaborating organisations: ¹UWA; ²DPIRD

This project utilises the 97-member core collection of subterranean clover, which represents around 80 per cent of the total genetic diversity within the known 10,000 accessions of the species, along with an additional 28 diverse cultivars. These 125 genotypes have been screened for their resistance against the most important diseases of subterranean clover, namely northern anthracnose (*Kabatiella caulivora*) – both Race 1 and 2 (seedling and adult resistance); rust (*Uromyces trifolii-repentis*); and the two most important root rot disease pathogens, *Phytophthora clandestina* and *Pythium irregulare*. The project also sought to determine the number and genome location of the resistance genes, identify potential parents for crossing to introduce to resistance genes to subterranean clover. This is now enabling the genetic control for resistance to each disease to be determined and molecular markers closely associated with resistance genes or QTLs to be produced.

We found significant variation among test genotypes against the foliar pathogens *Kabatiella caulivora* (northern anthracnose), *Uromyces trifolii-repentis* (rust) and *Erysiphe trifolii* (powdery mildew). The most resistant genotypes have now been identified, offering breeders a basis to breed new, more-resistant cultivars.

Marker-trait association (MTA) studies using phenotypic information obtained from core collection showed five markers on chromosomes 2, 3, 4 and 6 for and a further 11 markers on chromosomes 1, 2, 4, 5 and eight associated with *Kabatiella* resistance. These quantitative trait loci can now be used in marker-aided selection programs and will allow more rapid development of new subterranean clover cultivars highly-resistant against *Kabatiella*.

This project is expected in future to help lead to a reduction of current high levels of damage to subterranean clover pastures caused by the major foliar and soilborne pathogens across Australia by developing more resistant varieties.

This research is supported by RIRDC.

10: Contrasting genotype resistances to northern anthracnose disease (*Kabatiella*); highly resistant genotype (LHS) and highly susceptible genotype (RHS). Photo: Martin Barbetti.



9



10

Characterization of rice blast races present in Australia

Project team: Dr Vincent Lanoiselet² (leader; vincent.lanoiselet@agric.wa.gov.au), Mr Dolar Pak¹, Dr Ming Pei You¹, Professor Martin Barbetti¹

Collaborating organisations: ¹UWA; ²DPIRD

Rice blast (*Pyricularia oryzae*) is an important emerging disease on commercial rice in Australia, recently becoming more widespread and severe in northern regions. A survey of fungal pathogens on wild rice in north-eastern Australia highlighted the importance of wild rice (*Oryza australiensis*) as a reservoir for blast and other pathogens to infect commercial rice expanding into these northern areas. Overseas, other poaceous plants have been shown as alternative hosts and/or reservoirs of blast.

This project investigated the role of other nearby crops, such as wheat, barley, corn, and weeds, as reservoirs for blast inoculum survival and to understand the epidemiology of blast diseases across potential susceptible hosts.

Studies highlighted the virulence of rice blast *P. oryzae* isolates in Australia to wheat, barley, wild oat, ryegrass, phalaris and corn.

This potential for cross-infection of rice blast *P. oryzae* isolates onto alternative hosts sounds a warning for important grain crops such as wheat, barley and commercial rice, which are often grown or rotated near wild rice populations.

Our findings highlight the potential for outbreaks of blast on important Australian poaceous grain crops via inoculum surviving and/or accumulating in a range of readily-available host reservoirs. This is potentially an increasing problem as, as environmental conditions become more favourable for blast due to climate change leading to increased summer rainfall.

This research is supported by RIRDC.

11: Typical symptoms of blast disease on diverse poaceous hosts.
Photo: Dolar Pak.

Wind spread of plant viral pathogens into northern Australia

Project Team: Adjunct Professor Roger Jones¹ (leader; roger.jones@uwa.edu.au); Mr Solomon Maina¹ (PhD Student), Dr Owain Edwards², Dr Brenda Coutts³, Professor Martin Barbetti¹, Dr Ming-Pei You¹

Collaborating organisations: Co-operative Research Centre for Plant Biosecurity (CRC-PB); ¹UWA; ²CSIRO; ³DPIRD

To examine possible genetic connectivity between crop viruses found in south-east Asia and northern Australia, *Papaya ringspot virus* biotype W (PRSV-W) and *Zucchini yellow mosaic virus* (ZYMV) isolates from cucurbits growing in East Timor and northern Australia were studied. East Timorese samples were sent to Australia on FTA cards. The samples were subjected to high throughput sequencing.

When the 17 complete PRSV genomic sequences obtained were compared with 32 others, the five from East Timor were in a different major phylogroup from the 12 Australian sequences. Moreover, the East Timorese and Australian sequences each formed their own minor phylogroups. Recombination analysis revealed 13 recombination events amongst the 49 complete genomes. Two isolates from East Timor (TM50, TM32) and eight from Genbank were recombinants, but all 12 Australian isolates were non-recombinants. No evidence of genome connectivity between Australian and south-east Asian PRSV populations was obtained.

When the 15 complete ZYMV genomic sequences obtained were compared with 41 others, those from East Timor and Kununurra (three per location) and single sequences from Singapore and Reunion Island were in major phylogroup B. The seven Broome and two Darwin sequences were in different minor phylogroups within major phylogroup A. Analysis of all 56 complete genomes found recombination in 12 (87 per cent) and two (five per cent) sequences from northern Australia/south-east Asia and the rest of the world respectively, the former's high frequency indicating selection for tropical conditions. Both parents of the recombinant Kununurra sequences were East Timorese. Phylogenetic analysis, nt sequence identities and recombination analysis provided firm evidence of connectivity between sequences from Kununurra and East Timor.

This finding has important biosecurity implications over entry of viral crop pathogens into northern Australia.

In addition, additional viruses detected in cucurbit and other crop samples were sequenced.

12: Foliage of a ZYMV-infected pumpkin plant showing yellow mosaic and leaf deformation.

Emerging foliar diseases of canola

Project team: Professor Martin Barbetti (leader; martin.barbetti@uwa.edu.au), Dr Ming Pei You, Ms Margaret Uloth, Dr Niroshini Gunasinghe, Mr Akeel Mohammed

In Australia, in recent years, increased levels of diseases such as white leaf spot (*Pseudocercospora capsellae*), powdery mildew (*Erysiphe cruciferarum*), downy mildew (*Hyaloperonospora parasitica*) and *Alternaria* have been observed in canola (*Brassica napus*) and related Brassica crop species. Historically, all are assumed nationally to be able to cause significant losses and there is considerable evidence that they all, individually and together, are important diseases that significantly decrease current grain yields of canola. However, all four diseases are currently considered as 'emerging diseases', as disease incidences and severities have in general become more prominent in recent years but their incidence, epidemiology, severity and impacts remain to be defined. This project aimed to provide a better understanding of these diseases' epidemiology and, thereby, produce better management strategies to deal with them. We found varying levels of disease resistance in different *Brassica* species and cultivars, which offers options for using more resistant cultivars in areas where disease is severe, and also presents opportunities for future breeding of disease resistant commercial cultivars.

We determined host resistance against white leaf spot across 117 *B. napus*, 11 *B. juncea*, four *B. rapa*, five *B. oleracea*, eight *B. fruticulosa* and one *B. carinata* genotypes. While *B. rapa* and *B. oleracea* showed best resistance, more than 10 Australian commercial cultivars also demonstrated very high resistance to white leaf spot disease, with commercial cultivars Oscar and Stubby considered to be highly resistant.

Testing of 131 Brassicaceae varieties, including 109 Australian canola varieties (*B. napus* and *B. juncea*) and 22 diverse Brassicaceae (including *B. napus*, *B. carinata*, *B. juncea*, *B. nigra*, *B. rapa*, *Crambe abyssinica* and *Raphanus sativus*) highlighted excellent resistance to downy mildew. Of the canola cultivars, hybrids Hyola 444 TT, Hyola 500 RR, Hyola 504 RR, Pioneer, 46Y78, Pioneer 45Y77 and Hyola 650 TT, and the non-hybrid variety ATR-Eyre showed high level resistance.

Resistance to powdery mildew was assessed in 112 current and historic Australian canola (*B. napus*) cultivars and five cultivars of mustard (*B. juncea*) cultivars. For *B. napus*, cultivars with the greatest potential for reducing the impact of powdery mildew in the field were Trooper, Bravo TT, Summit, Tumbly, Narendra and Hyola 650TT. For *B. juncea*, SaharaCL and XceedX121CL were the most resistant

This research is supported by GRDC.

13: Typical leaf spotting from early downy mildew infection on canola. Photo: Martin Barbetti.





Pre-breeding of canola

Project team: Professor Wallace Cowling (leader; wallace.cowling@uwa.edu.au), Ms Jasenka Vuksik, Ms Roz Ezzy

Collaborating organisations: UWA; NPZ Australia Pty Ltd (subsidiary of NPZ Lembke, Germany)

We evaluated the effectiveness of new mating designs from animal breeding, based on optimal contribution selection (OCS) on an economic index. OCS provided superior genetic gain with reduced rates of population inbreeding in crop pre-breeding (Cowling et al. 2017). This research has been applied to our canola pre-breeding programme.

As in animal breeding, the new approach is based on best linear unbiased prediction (BLUP) of breeding value for yield and other complex traits, combined into an economic index of genetic value in \$/ha. BLUP or genomic BLUP values are calculated for grain yield, disease resistance and seed quality. Data are integrated across cycles of selection to provide improved predictions.

The results from the canola pre-breeding project are being translated into commercial canola hybrids by the project funder, NPZ Lembke, Germany. NPZ has licensed or sold canola hybrids from the UWA pre-breeding programme to several partners in Australia and internationally.

This research is supported by NPZ Australia Pty Ltd.

14: Ms Rozlyn Ezzy (left) and Jasenka Vuksic (right) carrying out canola crossing in the glasshouse, with 250 matings following a design generated by optimal contributions selection. Photo: Wallace Cowling.



National and international collaboration in design of crop breeding programs

Project team: Professor Wallace Cowling¹ (leader; wallace.cowling@uwa.edu.au), Hackett Professor Kadambot Siddique¹, Dr Rob Banks², Dr Li Li², Emeritus Professor Brian Kinghorn², Professor John Hickey⁴

Collaborating organisations: ¹UWA; ²University of New England; ³Roslin Institute, University of Edinburgh.

Professor Cowling undertook sabbatical leave in June – August 2017, during which he visited University of New England, Australia, and University of Edinburgh, Scotland, to undertake research on design of crop breeding programmes.

In June 2017, Professor Cowling visited University of New England where he worked with Dr Li, Dr Banks and Professor Brian Kinghorn to compare traditional tandem selection with index selection and optimal contributions by modelling. This research will be published in 2018.

In July-August 2017, Professor Cowling visited Dr John Hickey, Roslin Institute, University of Edinburgh, on sabbatical to explore genomic selection methods for hybrid breeding. This research will be published in 2018.

This research is supported by UWA, Australia Africa Universities Network, Syngenta Foundation for Sustainable Agriculture.

15: Professor Wallace Cowling (left) on sabbatical with Professor John Hickey, Roslin Institute, University of Edinburgh, in July 2017, to explore hybrid breeding methods with genomic selection. Photo: Hickey Laboratory, University of Edinburgh.



Expanding the Brassica germplasm base through collaboration with India and China

Project team: Professor Martin Barbetti¹ (leader; martin.barbetti@uwa.edu.au), Dr Ming Pei You¹, Dr Niroshini Gunasinghe¹, Professor Surinder Banga², Dr Shashi. Banga², Dr Xi Xiang Li³, Professor Phil Salisbury⁴, Dr Allison Gurung⁴

Collaborating organisations: ¹UWA; ²Punjab Agricultural University; ³Chinese Academy of Agricultural Science; ⁴University of Melbourne

Sclerotinia rot caused by *Sclerotinia sclerotiorum* is a very serious disease across oilseed and vegetable *Brassica*-growing regions worldwide, including Australia. Effective host resistance is urgently needed if it is to be economically managed. We sought to identify new sources of resistance to *S. sclerotiorum* across diverse oilseed, forage and vegetable crucifers, including some wild and/or weedy species, and also within and/or derived from *Brassica carinata* (mustard).

Field resistances against Sclerotinia rot (*Sclerotinia sclerotiorum*) were determined in 52 Chinese genotypes of *Brassica oleracea* var. *capitata*, 14 Indian *Brassica juncea* genotypes carrying wild weedy Brassicaceae introgression(s) and four carrying B-genome introgression, 22 Australian

commercial canola varieties, and 12 *B. napus* and *B. juncea* genotypes of known resistance. Overall, 65 per cent of the *B. oleracea* var. *capitata* genotypes from China showed the highest levels of stem resistance; a level comparable with the highest resistance ever recorded for oilseed *B. napus* or *B. juncea* from China or Australia. One Indian *B. juncea* line carrying weedy introgression displayed a significant level of both stem and leaf resistance. However, the vast majority of commercial Australian canola varieties fell within the most susceptible 40 per cent of genotypes tested for stem disease.

We found no correlation between expressions of stem versus leaf resistance, suggesting their independent inheritance.

A few Chinese *B. oleracea* var. *capitata* genotypes that expressed combined extremely high-level stem and leaf resistance will be particularly significant for developing new Sclerotinia resistant horticultural and oilseed *Brassica* varieties.

This research is supported by GRDC.

16: Test rows of different *Brassicaceae* species and genotypes under test for resistance to Sclerotinia stem rot. Photo: Martin Barbetti.

Understanding resistance in Brassicaceae to Sclerotinia Stem Rot at a molecular level

Project team: Professor Martin Barbetti¹ (co-leader; martin.barbetti@uwa.edu.au), Professor Surinder Banga² (co-leader), Dr Kusum Rana², Dr Chhaya Atri², Dr Mehak Gupta², Dr Javed Akhatar², Dr Prabhjot Sandhu², Dr Nitin Kumar², Dr Ravinder Jaswal², Dr S Banga².

Collaborating organisations: ¹UWA; ²Punjab Agricultural University

Sclerotinia rot caused by *Sclerotinia sclerotiorum* is a very serious disease across oilseed and vegetable *Brassica*-growing regions worldwide, including mustard in India and canola in Australia. Understanding how Sclerotinia resistance can be influenced by uncharacterized genes contributing to overall phenotypic expression will help in developing resistant cultivars. In a long-standing *Brassica* disease collaboration with Punjab Agricultural University in India, resistance from a wild *Brassicaceae* species, *Brassica fruticulosa* was introgressed into mustard (*Brassica juncea*).

We determined resistance responses of these introgression lines to Sclerotinia following stem inoculations under disease-conducive conditions. Subsequently, molecular mapping techniques showed these lines possessed very high levels of Sclerotinia resistance.

For the first time, it was found that resistance to Sclerotinia in Indian mustard is influenced by at least ten significant marker trait associations for genes CNUm157-2, RA2G05, CNU-m353-3, CNU-m442-5, ACMP00454-2, ACMP00454-3, EIN2-3-1, M641-1, Na10D09-1 and Na10D11-1.

These findings are very exciting, given that the only real prospect for long-term, cost-effective management of Sclerotinia is in developing highly-resistant varieties.

Results from association mapping studies clearly demonstrated that *B. juncea*-*B. fruticulosa* ILs have significant potential breeding applications, offering mustard and canola breeders a powerful new tool to optimise genetic variation available within wild *Brassica* species. Ultimately, developing resistant cultivars will enable much more effective management of this devastating pathogen worldwide.

Currently farmers rely mainly on fungicide sprays to manage the disease, but these often provide poor or inconsistent control. Further, forecasting this disease has proven unreliable, so fungicides are often wasted in cases where little disease would have eventuated anyway, adding to the already high production costs for low-input farming systems such as in Australia and India.

This research is supported by UWA and Punjab Agricultural University.

17: Typical Sclerotinia stem rot of canola showing girdling of stem that will subsequently lead to plant collapse. Photo: Martin Barbetti.

Wind spread of plant viral pathogens into northern Australia

Project team: Adjunct Professor Roger Jones¹ (leader; roger.jones@uwa.edu.au), Mr Solomon Maina¹ (PhD candidate), Professor Martin Barbetti¹, Dr Mingpei You¹, Dr Owain Edwards², Dr Brenda Coutts³

Collaborating organisations: ¹UWA; ²CSIRO; ³DPIRD

Australian crops face potential threats from new virus diseases via viruiferous insect vectors blown in wind currents from Indonesia, East Timor and PNG. It is likely that climate change will increase the frequency and intensity of these wind currents. This study sought to establish the extent to which economically important viral pathogens of crops are arriving in northern Australia via wind-borne insect virus vectors.

Biological studies were undertaken with representative isolates from Australia. Samples from East Timor and PNG were transported on FTA cards, a common method used to transport and store DNA material without the risk of any biosecurity concerns arising from new virus introductions. Virus genomes from plant samples collected in northern Australia from Broome, Kununurra, Darwin and Cairns/Ayr were compared with virus genomes obtained from the same crops in East Timor and PNG. We investigated genetic connectivity between isolates of the same viruses from East Timor, PNG and Northern Australia. Our main focus was on viruses of cucurbits and sweet potato as these crops produced many virus genomes, but several additional genomes were also obtained from other crops.

We found evidence of genetic connectivity between the genomes of *Zucchini yellow mosaic virus* from cucurbits from Kununurra and East Timor, *Papaya ringspot virus* from cucurbits from across northern Australia and PNG, and *Sweet potato feathery mottle virus* from sweet potato from East Timor, Cairns and Kununurra. However, we found no evidence of connectivity with *Sweet potato virus C*. Viruses represented by few sequences were published as genome announcements, but the *Zucchini yellow mosaic virus*, *Papaya ringspot virus*, *Sweet potato feathery mottle virus* and *Sweet potato virus C* studies constituted full research papers.

This research is supported by CRC for Plant Biosecurity.

18: Capsicum plant infected with Pepper veinal yellows virus in the field in Kununurra. Photo: Roger Jones.

Curtailling and managing exotic fungal spore incursions into Australia

Project team: Professor Martin Barbetti¹ (leader; martin.barbetti@uwa.edu.au), Ms Papori Barua¹, Dr Ming Pei You¹, Dr Kirsty Bayliss², Dr Vincent Lanoiselet³

Collaborating organisations: ¹UWA; ²Murdoch University; ³DPIRD

This project investigated how well spores of exotic fungal pathogens survive on different substrates and under different conditions. Fungal spore survivability has important implications for biosecurity. Preliminary work conducted by the Cooperative Research Centre for National Plant Biosecurity (CRCNPB) demonstrated that it is possible to detect fungal spores on various materials. Our project has extended the CRCNPB work to define the relative risks of different carrier materials (e.g., clothing, skin, souvenirs, metal, wood, etc) transporting fungal spores into Australia. Additionally, we are investigating ways to mitigate these risks by investigating decontamination options.

Our experiments focussed on the northern anthracnose pathogen *Kabatiella caulivora*, which causes fungal disease on clovers and trefoil (*Trifolium* species). We found that the fungal conidia (type of spore) and resting hyphae (fungal structure), were effectively carried by, and maintained long-term viability on, a range of materials, including metals, fabrics, woods and plastics.

- At 23°C/8°C, day/night, conidia and resting hyphae remained viable on steel, corrugated iron, galvanized steel, all tested fabrics, wood and random mixed materials for up to eight months.
- At 36°C/14°C day/night, conidia and resting hyphae remained viable for up to eight months, but only on cotton, denim, fleece, silk, leather, paper, plastic and all wood materials.
- At 45°C/15°C day/night, conidia and resting hyphae remained viable up to eight months only on fleece wool, jarrah wood (*Eucalyptus marginata*) and paper.

Carrier materials differed significantly in their abilities to retain conidia and resting hyphae after being washed.

We confirmed that after eight months, conidia and resting hyphae retained metabolic activity. After this time, *K. caulivora* colonies successfully re-established on potato dextrose agar.

Our findings confirmed the critical importance of materials as long-term carriers of viable *K. caulivora* conidia and resting hyphae, highlighting the potential for spread of a highly virulent *K. caulivora* race within and outside Australia via farming equipment, clothing and other associated materials.

These results also have wider biosecurity implications for the transportation of fungal-infested carrier materials previously considered as low risk.

This research is supported by CRC Plant Biosecurity.

19: Light micrograph showing the formation of thick walled resting hyphae and melanisation (darker brown colour) of hyphae of *Kabatiella caulivora* eight months after inoculation. Photo: Papori Barua.



17



18



19



Identification and characterisation of resistance (*R*) genes in *Brassica napus* against the fungal pathogen *Leptosphaeria maculans*

Project team: Professor Jacqueline Batley¹ (leader; jacqueline.batley@uwa.edu.au), Professor Martin Barbetti¹, Professor Dave Edwards¹, Dr Thierry Rouxel², Dr Marie-Hélène Balesdent², Ms Ting Xiang Neik¹, Ms Bénédicte Ollivier², Dr Philipp Bayer¹, Ms Anita Severn-Ellis¹, Dr Aneeta Pradhan¹, Dr Chon-Kit Kenneth Chan¹, Mr Armin Scheben¹, Mr Yuxuan Yuan¹, Ms Yueqi Zhang¹

Collaborating organisations: ¹UWA; ²National Institute for Agricultural Research (INRA), France.

Canola (*Brassica napus*) may suffer yield losses up to 90 per cent when heavily infected by the fungal pathogen *Leptosphaeria maculans* (blackleg disease). Several resistance (*R*) genes have been mapped in the *B. napus* genome, but the characteristics of these genes, including their structure and function, are yet to be determined, and only two *R* genes have been cloned. There is a strong need to explore more resources of *R* genes for breeding resistant cultivars.

This project aims to characterise the *R* genes in *B. napus* against *L. maculans* using phenotypic and next-generation sequencing methods.

This year, 19 *B. napus* genotypes were screened using a series of *L. maculans* isolates, characterised for their avirulence (*Avr*) genes. Based on past phenotypic studies, the canola genotypes were predicted to each carry one or two *R* genes against *L. maculans* (*Rlm*). Our study confirmed most of the genotypes to carry the *Rlm* genes as predicted, and also found new *R* gene interactions.

Short term research work at the French National Institute for Agricultural Research (INRA), France allowed us to extend our phenotypic study using the French isolate collection. Comparison of phenotypic outcomes using isolates from different countries, but the same plant sample, showed that the plant samples behave quite differently. There are a few possible reasons for this:

- The isolates are highly adapted to local conditions so the *R-Avr* gene interaction under different environments may differ.
- There may also be new *R-Avr* gene interactions.
- There could be heterogeneity in the plant material due to cross pollination during seed bulking, or even sample mix up.

This highlights the need to confirm the genetic material of the plant for *Rlm* gene validation.

We have also identified candidate SNPs that are highly associated with the resistant and susceptible phenotype in *B. napus* hybrids/lines carrying *Rlm7*. These *Rlm7* plants were sourced from INRA, France. Further molecular work will be performed on these plants to identify and confirm the candidate genes responsible for the resistance trait.

This research is supported by UWA Scholarship for International Research Fees (SIRF), UWA International Living Allowance Scholarship, and UWA Convocation Postgraduate Research Travel Award.

20: Disease screening on *B. napus* genotypes sourced from Australia using French isolate collection under controlled environment. Experiment was conducted at INRA, Grignon. Photo: Ms Ting Xiang Neik.



Ammonium toxicity and resistance in canola genotypes

Project team: Mr Omar Al-Awad
(PhD candidate; omar.al-awad@research.uwa.edu.au),
Professor Zed Rengel, Emeritus Professor Alan Robson

Ammonium toxicity is a common soil problem that can inhibit crop growth; most crops have poor resistance to ammonium. Canola is particularly sensitive to ammonium (NH_4^+), but variable resistance may exist among different canola genotypes.

This PhD project aims to characterise resistance of canola genotypes to ammonium and assess the role of varying ammonium:nitrate ($\text{NH}_4^+:\text{NO}_3^-$) ratios and biochar soil amendments in modifying responses of canola genotypes to NH_4^+ toxicity.

Eight ammonium chloride treatments and five calcium nitrate treatments were tested using one canola genotype grown for 35 days in the glasshouse. In the second experiment, 30 canola genotypes were screened at selected concentrations of ammonium using nitrate supply as the control.

High ammonium application (60 mg N/kg soil) significantly decreased the dry weight of shoots and roots and acidified the rhizosphere soil from pH 5.9 to 5.6. We found genotypes varied widely in their sensitivity to high ammonium application, with Tarcoola-22, SC01-3 and Zy001 having greater shoot dry weights and the highest shoot nitrogen concentration than the other genotypes, suggesting the strongest resistance to ammonium toxicity. Genotypes SC13-3, Tarcoola-22 and Zy001 had root dry weight up to 35 per cent higher at high soil ammonium compared with the nitrate control. In contrast, genotypes SC03-1, AV-Opal and Zhongshuang4B showed the largest reduction in shoot weight, and genotypes AV-Opal, Charlton and SC03-1 showed the largest reduction in root weight at high ammonium application. The residual ammonium in soil at harvest after 35 days was higher in the sensitive than the resistant genotypes, suggesting lower

ammonium utilisation in the sensitive genotypes. Our results indicate that it is possible to select canola genotypes resistant to high ammonium concentrations in soil.

We also tested two sensitive and two resistant canola genotypes during vegetative stages of growth to determine the effect of nitrate:ammonium ratios. Nitrogen at 60 mg/kg soil was provided at five different $\text{NH}_4^+:\text{NO}_3^-$ ratios (0:100, 100:0, 25:75, 50:50 and 75:25).

At the ratio 25:75 of ammonium:nitrate, resistant genotype Zy001 had significantly greater shoot dry weight, and fine and coarse root length than sensitive genotype SC03-1. At the ratio 50:50 of ammonium:nitrate, genotypes Zy001 and Tarcoola-22 had significantly longer fine root length compared with genotype SC03-1. In contrast, all genotypes had lower shoot dry weight and coarse root length at the ratios 100:0 and 75:25 of ammonium:nitrate compared with the other ratios. Genotypes SC03-1 and Zhongshuang4B were more sensitive to high soil ammonium ratio (100:0) in regards to shoot dry weight and fine and coarse root length.

We also tested a range of biochar treatments (e.g. types and concentrations of biochar) with a potential to alleviate ammonium toxicity in canola. We then investigated the mechanism of ammonium toxicity in soil following biochar applications. This experimental work is now complete and the thesis will be submitted before February 2019.

This research is supported by the Iraqi Government's Higher Committee for Education Development Scholarship.

21: Canola shows varying response to ammonium concentrations: (L-R) sensitive canola genotype at 60 mg $\text{NH}_4^+\text{-N}$, resistant canola genotype at 60 mg $\text{NH}_4^+\text{-N}$, canola genotype at 60 mg $\text{NO}_3^-\text{-N}$. Photo: Omar Al-Awad.



Comparative performance of *Lupinus albus* L. cultivars in response to soil pH

Project team: Professor Hans Lambers¹ (leader; hans.lambers@uwa.edu.au), Ms Omnia Arief^{1,2} (PhD candidate), Dr Jiayin Pang¹, Professor Kamal Shaltout³

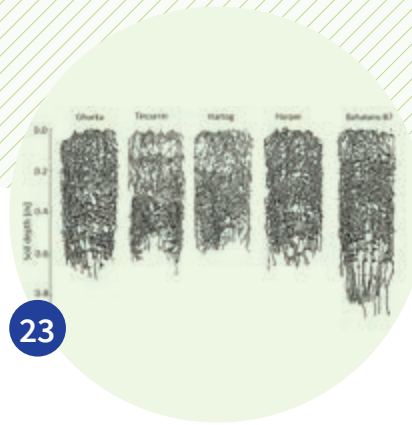
Collaborating organisations: ¹UWA; ²Benha University, Egypt; ³Tanta University, Egypt

This study compared the response of two cultivars of lupin (*Lupinus albus* L.) to alkaline soil. We used the tolerant Egyptian cultivar P27734, which naturally grows in pH9 soil, and the pH-sensitive Australian cultivar Kiev Mutant.

Plants were grown in a glasshouse using three pH levels (5.1, 6.7 and 7.8) and the cultivars' performance evaluated. We measured leaf, stem and shoot dry masses, leaf and root area, and carboxylate exudates, to compare the cultivars at different soil pH values.

The greatest biomass production and carboxylates exudation were observed at alkaline treatment. We found that is the only trait that renders the Egyptian cultivar P27734 more tolerant to alkaline soil is its larger seed size, rather than any differences in biomass partitioning, root morphology or the exudation of carboxylates.

22: *Lupinus albus* cv Kiev showing vigorous and healthy growth in alkaline soil. Photo: Omnia Arief.



The physiology and productivity of wheat (*Triticum aestivum* L.) genotypes with contrasting root system size under drought stress

Project team: Ms Victoria Figueroa Bustos¹ (PhD Candidate; victoria.figueroabustos@research.uwa.edu.au, Hackett Professor Kadambot Siddique¹, Adjunct Professor Jairo Palta^{1,2}, Dr Yinglong Chen¹

Collaborating organisations: ¹UWA; ²CSIRO

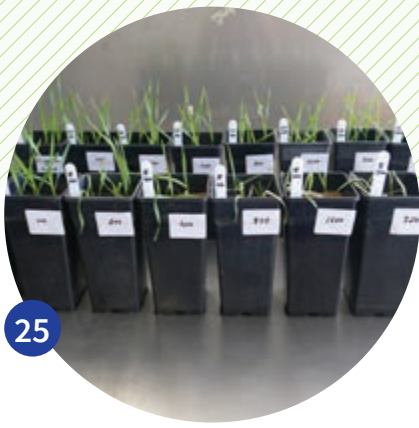
Climate change is affecting the amount and distribution of rainfall, with repercussions for crop production in several regions of the world. Wheat is the most important crop in Australia. However, soil water availability impacts directly on wheat yield and quality. In dry environments, access to soil water is critical for crops to maintain yield stability; water deficits will reduce photosynthesis, biomass and yield. The form and functions of a crop's root system are critical for accessing soil water to minimize water deficit. This project aims to determine the role of the root system size in conferring drought tolerance in wheat.

During 2017 we used rhizoboxes to characterised the root system and shoot characteristics of a set of wheat genotypes with contrasting root system size in the soil. Our results showed that the phenology affects the root system size. Cultivars that took longer from sowing to anthesis had larger roots (both in root length and biomass) compared to early flowering ones. More root branching and thicker roots were found in cultivars with bigger root systems, especially in the first 40cm. Cultivars with larger root systems also had 25 per cent more leaf area and leaf biomass than cultivars with smaller root systems.

Based on these results we have selected wheat genotypes with different sized root systems and will study their responses to early and terminal drought stress.

This research is supported by UWA and CONICYT-Becas Chile.

23: Comparison of the non-invasive measured root distribution patterns of five genotypes with putatively contrasting root system.



Genetic analysis of herbicide tolerance in bread wheat (*Triticum aestivum* L.)

Project team: Professor Guijun Yan (leader; guijun.yan@uwa.edu.au), Ms Roopali Bhoite (PhD candidate), Dr Ping Si, Hackett Professor Kadambot Siddique

Wheat (*Triticum* spp.) is a major food source worldwide and comprises 65 per cent of WA's annual grain production. Weed infestation by broad-leaf and grassy weeds reduces wheat yield up to 50 per cent, making weed control an important aspect of crop management and effective weed control is economically vital for sustainable food production. An improved wheat variety tolerant to the herbicide metribuzin would help manage problematic weeds, such as brome grass (*Bromus* spp.), barley grass (*Hordeum* spp), ryegrass (*Lolium rigidum* Gaudin), silver grass (*Vulpia myuros* and *Vulpia bromoides*) and wild radish (*Raphanus raphanistrum* L.). Identifying resistance sources in wheat germplasm is a major challenge.

We investigated genetic variation of herbicide tolerance in 946 wheat diversity panels from six continents. We successfully identified the most contrasting genotypes for metribuzin tolerance. The tolerant source, Chaun Mai 25 from China is 56 per cent more tolerant than the known local tolerant cultivar Eagle Rock. The susceptible line, Ritchie, from England, is 43 per cent more susceptible compared to the local

known-susceptible cultivar Spear. A manuscript titled paper "Identification of new metribuzin-tolerant wheat (*Triticum* spp.) genotypes" has been published in Crop and Pasture Science.

We have mapped QTLs and identified genomic regions responsible for metribuzin tolerance. Presently, genetic studies of gene effects coupled with SNPs identification in diverse gene pools using 90K iSelect SNP genotyping assay are underway. Transcriptomic profiling of the most diverse genotypes via high throughput sequencing technologies will help identify the key genes and functional markers. The molecular tags/markers tightly linked with genes may be used in marker-assisted selection (MAS) for developing elite metribuzin tolerant wheat cultivars. This research, using transcriptome studies of susceptible and tolerant wheat varieties to decipher genes and key pathways involved in herbicide resistance, is a world first.

This research is supported by Research Training Programme (RTP).

25: Dose-response experiment carried out for tolerant Chuan Mai 25 (A) and susceptible Ritchie (B) exposed to various metribuzin doses. Photo: Roopali Bhoite.

Fate of Pre-Emergence Herbicides Intercepted by Residues in Conservation Agriculture Systems

Project team: Mr Yaseen Khalil¹ (PhD candidate; yaseen.khalil@research.uwa.edu.au), Dr Ken Flower¹, Hackett Professor Kadambot Siddique¹, Dr. Phil Ward^{1,2}, Dr Colin Piggin³

Collaborating organisations: ¹UWA; ²CSIRO; ³ACIAR

Pre-emergent herbicides are applied to the soil and many require some incorporation. However, these herbicides can be intercepted by stubble, which may reduce weed control in no-tillage cropping systems. As stubble retention is a key component of NT systems in Australia, it is important to understand the factors, such as stubble and rainfall that influence the efficacy of pre-emergent herbicides in Western Australia. This research has three main objectives:

- Determine the effect of rainfall amount and intensity on leaching of trifluralin, pyroxasulfone and prosulfocarb from stubble.
- Investigate the effect of crop residue type and age on sorption and leaching of trifluralin, pyroxasulfone and prosulfocarb.
- Determine the effect of residue height, amount and orientation on pyroxasulfone interception, leaching and distribution in the soil and its weed control efficacy.

The experimental work for this PhD research is now finished. Briefly, three commonly used pre-emergent herbicides (trifluralin, prosulfocarb, pyroxasulfone) were applied at recommended rates with: different rainfall conditions (amount, timing, and intensity), different crop residue conditions (amount, moisture level in residue at time of herbicide application), different crop residue amounts (0, 1, 2, 4 t/ha), different crop residue types (wheat, barley, canola, chickpea, lupin) and ages (fresh, aged). In addition, the effect of crop residue height (0, 10, 20 and 30 cm standing stubble) amount (0, 1, 2 and 4 t/ha) and orientation (standing and horizontal) on pyroxasulfone efficacy in the field was tested. Research was conducted in the greenhouse/controlled conditions and in the field.

The PhD thesis is now being written and a number of papers are being prepared for publication. Pyroxasulfone leached easily from the residue into the soil for up to 14 days to potentially offer good weed control, prosulfocarb had intermediate leaching, while only a small amount of trifluralin leached from stubble with rain one day after application. Increased amounts of wheat residue intercepted more herbicide, with a large increase in interception from 2 to 4 t ha⁻¹. The amount of herbicide intercepted by barley and wheat residues was greater than for an equivalent amount of canola, chickpea or lupin residue and this was largely due to increased ground cover with cereal residues.

This research is supported by ACIAR/John Allwright Fellowship and Underwood PhD scholarship

26: Setting up the field experiment site and spraying herbicide at the Cunderdin location. Photo: Yaseen Khalil.

Evaluation and development of castor bean as a commercial crop in Australia

Project team: Hackett Professor Kadambot Siddique¹ (leader; kadambot.siddique@uwa.edu.au); Dr Yinglong Chen¹

Collaborating organisations: ¹UWA; Zenith Australia Group, Perth

Castor (*Ricinus communis* L), castor bean or castor-oil plant, is a perennial flowering species in the spurge family, Euphorbiaceae. Castor seed is one of the important non-edible oilseeds, having immense industrial and medicinal value. Castor plant and its products have long been utilised as traditional medicine and also as lamp and lubricant oil. The seeds contain 35 to 50 per cent oil that is rich in triglycerides, mainly ricinolein.

In Australia, castor plants are seen occasionally growing in parks, riversides, wastelands, road sides and near railway tracks, however it is not commercially grown here. This project sought to evaluate growth and productivity of castor seeds acquired from Australia and overseas, and to develop agronomic packages and production technologies to establish a profitable industry in WA.

Research in 2017 focussed on seed collection and establishing field trials at Shenton Park and Marvel Loch. We collected wild castor bean seeds in Perth and surrounding areas, grew seeds from imported Chinese materials through quarantine facilities at UWA Shenton Park Field Station, assessed the growth and productivity of castor seeds in controlled environments, field station and on-farm (Marvel Loch), and determined oil content of castor bean seeds from various collections in Perth and China.

We collected some 53 kg (about 272,000 seeds) from more than 120 individual sites in 46 suburbs in Perth and surrounds. Seed weights ranged from 10.5 to 39g per 100 seeds. The collections were categorised into 12 groups based on the collection location, but seed size and other characters were also taken into account. Seed oil content analysis, which ranged from 35.5 to 49.2 per cent. In September 2017, a large plantation trial (15 ha) was established at a farm in Marvel Loch. The seed germination rates, plant establishment and seed production varied vastly in different sites in the field, and among the tested seed groups. A follow-up small-scale trial with three irrigation stations was also established in Marvel Loch in December 2017.

This research is supported by Virtue Australia Foundation, Adelaide.

27: Castor plants at a farm trial at Marvel Loch. Photo: Yinglong Chen.

Farm-Scale Modelling for Predicting Spatio Temporal Carbon Sequestration as a System Resilience Measure in South Western Australia.

Project team: Emeritus Professor Lynette Abbott¹ (leader; lynette.abbott@uwa.edu.au); Ms Jolene Otway¹ (PhD candidate; jolene.otway@research.uwa.edu.au), Dr Louise Barton¹, Dr Jennifer Dungait², Mr Kevin Coleman², Mr John Clarke³, Ms Karen Holmes⁴, Mr Noel Schoknecht⁴

Collaborating organisations: ¹UWA; ²Rothamsted Research; ³CSIRO; ⁴DPIRD

This research aims to help transform poorly-performing farmland into long-term productive systems by combining local knowledge of farmland with existing research, publicly available data and simplified modelling tools. By examining rainfall behaviour across a farming system (hence the value derived) and drawing parallels between good and problem areas, carbon deposition, and other indicators, we plan to develop a simulation. This tool would show how poor areas may be improved and the extent to which these changes would benefit the soil, and hence landholder, for a specific location.

We have sampled two farms (at the end of winter and end of summer) to investigate the spatio-temporal variation of multiple soil physical and chemical properties. We conducted a bioassay to examine the comparable growth characteristics of plants within four different locations under a higher standardized watering regime and the behavior of mycorrhizal fungi under these conditions. This enabled us to identify relationships to use in the simulation tool where certain input data may not be readily available.

Publicly available data (weather and soil) for south-western Australia was collated, interpreted and automated into the model for use where no location specific input data is available or where average data is of interest relative to the farm in question. This data was integrated into the RothC carbon turnover model and the model was tested across the region, with tuning conducted against the publicly available soil carbon content data.

The final carbon simulation tool will also model carbon sequestration in south-western Australia under current and projected climatic conditions. This modelling will be location-specific, interactive and educational. The tool will take into account variations across individual farms and across south-western Australia more broadly. This will simplify the tool's use and enable detailed understanding of the impact of changing climate or land management practices where desired.

PhD student Jolene Otway attended the International Symposium on Soil Organic Matter held at Rothamsted Research (UK) and presented the alpha version of the modelling tool to Kevin Coleman, the co-developer and programmer of the Rothamsted Carbon Model (RothC), who provided invaluable feedback and support for Jolene's work.

This research is supported by Robert and Maude Gledden Postgraduate Research Scholarship.

28: Significant variability was seen across the two properties sampled; none more evident than the soil colours observed during the Particle Size Analysis. Photo: Jolene Otway.



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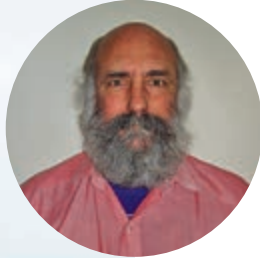


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2

Sustainable Grazing Systems

Theme leaders

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Research undertaken in the Sustainable Grazing Systems theme has contributed to the crop-pasture and animal-production nexus, conducted in close cooperation with other national and international Research, Development, Extension and Adoption (R,D,E and A) partners.

This theme looks at the sustainable contribution of livestock industries to global food supply. The focus is on resolving five key problems. These are:

- the consumption of human food by livestock
- livestock species and genotypes that are poorly adapted to the local environment
- poor animal health and welfare resulting in sub-optimal productivity
- provision of adequate animal nutrition and
- the environmental footprint.

Mixed crop-pasture systems in WA are largely sheep-based, with a smaller cattle component. The feed base is dominated by the use of annual pastures, predominantly subterranean clover. It is essential that grazing systems are sustainable, to continue providing feed for the various animal-production systems in Western Australia.

UWA has a current focus on development of phosphorus efficient pastures that can maintain productivity on lower soil phosphorus levels. The interaction between pastures and crops are critical to the management of weeds, including herbicide resistant weeds, because within the pasture phase there is a clear pathway to their management. Aspects of efficient nutrition use and disease control also show promise to alleviate issues that are problematic in the cropping phase alone.

Detection and mitigation of the impact of heat stress on productivity in Australian dairy cattle

Project team: Ms Shilja Shaji¹ (PhD candidate; shilja.shaji@research.uwa.edu.au), Associate Professor Dominique Blache¹, Professor Shane Maloney¹, Dr Hayley Norman², Dr John Milton³

Collaborating organisations: ¹UWA; ²CSIRO; ³Independent Lab Services

PhD candidate Shilja Shaji from India began her studies at UWA in 2017. The project focuses on the physiological effects of heat stress (HS) in lactating dairy cattle. Shilja aims to develop early detection and mitigation strategies to reduce the impact of HS on milk production.

The project comprises three approaches. First, she will investigate the use of Near Infrared Spectroscopy (NIRS) to detect HS in lactating dairy cattle from milk and/or plasma samples. NIRS is known for its speed, precision, experimental simplicity and most importantly, being a cost-effective and reproducible analytical technique. It will be validated and used to detect HS in dairy cattle without having to measure classical markers of heat stress such as body temperature or sweating.

Second, Shilja will assess the individual variability in milk production in response to HS and identify polymorphisms in genes that are present in HS tolerant animals. Finally, she will test strategies for the mitigation of HS by analysing the effect of supplementation of antioxidants, and Vitamins C and E in lactating dairy cattle during HS.

Shilja has already established connections with Western Dairy, the WA branch of Dairy Australia, and The Victorian Dairy Production Sciences Research Team (DEDJTR), based at Ellinbank (Victoria). Shilja has strong connections with Western Dairy and therefore producers have been aware of her objectives from the beginning of her project. Shilja is the recipient of a UWA scholarship, the prestigious Tim Healey Memorial Scholarships and a scholarship from Western Dairy.

This project is supported by UWA, Western Dairy and the Tim Healey Memorial Scholarship.

1: PhD candidate Shilja Shaji is using near infrared spectroscopy to detect heat stress in lactating dairy cattle from milk and plasma samples. Photo Dominique Blache.

Environmental factors limiting the production and persistence of forage legumes in southern Australia

Project team: Mr Daniel Kidd¹ (PhD candidate; daniel.kidd@uwa.edu.au), Associate Professor Megan Ryan¹, Professor Tim Colmer¹, Dr Richard Simpson²

Collaborating organisations: ¹UWA; ²CSIRO Agriculture and Food

In Daniel's PhD research he is investigating the soil and environmental constraints to production of serradella (*Ornithopus* spp.). The project is part of a national project that is focussed on the development of low-phosphorus (P) grazing systems. Serradella species have previously been found to have a lower external P requirement than other annual pasture legumes, such as subterranean clover, due to root system morphology that enables efficient exploration of soil for P. The overall aim of Daniel's PhD research is to increase the adoption of serradella pastures in the high rainfall zone.

In 2017, Daniel focussed on the variation in tolerance of serradella species and cultivars to high soil aluminium (Al) and manganese (Mn). Current information on this topic is largely anecdotal. Responses to Al and Mn were examined initially in solution culture to create a dose response curve. Significant variation in tolerance to both elements was evident among cultivars. A pot experiment using field soil with an Al-toxic subsoil was then conducted to validate the findings from the solution culture experiments. It also examined the capacity of serradella to alter its root distribution in response to Al, that is, to avoid the subsoil. A range of treatments were imposed to manipulate pH and Al and Mn level. For instance, subsoil Al and pH were ameliorated with lime or gypsum, and Mn was added. The results from these experiments will provide new knowledge of differences in Al and Mn tolerance among serradella cultivars and allow livestock producers to make better cultivar choices.

In 2017, Daniel was awarded the inaugural Calenup research scholarship. He will use the associated funding to conduct a field experiment at Merredin Research station in 2018. The experiment will compare the growth response of serradella cultivars (with a range of tolerance to Al) in limed and control plots and provide field validation for his controlled environment studies.

This research is supported by the Australian Government Department of Agriculture and Water Resources, MLA, Dairy Australia and AWI.

2: Daniel Kidd in his pot study examining the growth response of serradella cultivars to field soil with an aluminium (Al) toxic subsoil. Subsoil treatments included the addition of lime or gypsum to ameliorate pH and Al and the addition of Mn to induce toxicity. Photo: Daniel Kidd.

The potential for raising pasture productivity in the farming zone of southern Australia: review of the evidence

Project team: Dr Ann Hamblin (ann.hamblin@uwa.edu.au)

Pasture productivity on southern Australian farms has remained below the potential expected by the extent of improved pastures and associated infrastructure. I sought to identify why this is the case.

Surveys conducted between 1997-2017 show much pasture on farms is of low productivity, under-utilised and prone to environmental degradation. Farms have maintained profits and productivity growth by cutting input costs or expanding their operating area, not by investing in pasture improvement. Up until 2010, rain-fed cropping achieved greater productivity than animals, so low investment in pastures was understandable, but crop productivity growth has slowed and the profitability of red meats and wool production has increased in recent years.

The southern red meat industry could be substantially increased by greater investment in pasture renovation, but despite major research initiatives, there has been limited adoption of new pasture and fodder legumes, which have been released by breeding programmes to overcome specific soil constraints. Why do producers remain reluctant to invest in pastures?

The lack of investment on farm relates to constraints throughout the value chain. Recent enquiries into the meat processing and marketing industries reveal poorer dissemination of pricing information through the livestock value chain compared with grains. There are higher labour costs with sheep than with cropping, and faster rates of return on investment in crops than pastures.

Physical challenges to pasture production include reduced winter rainfall shortening the grazing period, and widespread acidification of pasture land. Matching seasonal feed availability to reproductive cycles and market demand is complex with the current predominance of ewe flocks and lamb production. Innovative producers now focus attention on alternative feedstocks to pasture, planting perennial fodder shrubs, winter grazing of annual crops, and relying on grain feeds for finishing.

Scale is highly related to profitability; economies of scale on farm, closeness of settlement, and distance to saleyards and processors. Many animal-based farms in high rainfall districts are too small to capture price benefits. Where farms are close to regional urban centres there is more incentive to run them for rents than productivity. Although over 95 per cent of farms in Australia remain family companies, their business model (small, independent operators) does not provide adequate bargaining power to maximise profitability. Proposals for cooperative structures, venture capital syndicates, and other financial arrangements are seldom adopted, and vertical integration of production, processing and marketing is restricted. Pastures may continue to be a declining asset under these conditions.





Roles of miRNAs in the responses of Merino sheep genetically selected for worm resistance to infection with nematode parasites

Project team: Adjunct Associate Professor Johan Greeff^{1,2} (leader; johan.greeff@dpird.wa.gov.au), Professor Graeme Martin¹, Professor Philip Vercoe¹, Dr Alfred Chin Yen Tay¹, Mr Shamshad Ul Hassan² (PhD Candidate)

Collaborating organisations: ¹UWA; ²DPRID

Gastrointestinal worms, explicitly helminth nematodes, cause diarrhoea and diarrhoea is the main predisposing factor to flystrike in the winter rainfall regions of Australia. These are major problems faced by Australian industries based on Merino sheep, and lead to huge annual economic losses. A major opportunity has arisen with the development of the world's most worm-resistant Merino flock by breeding for resistance over a period of 25 years. In addition to offering a solution to the costs of worm and flystrike management, genetic selection aligns with the vision of 'clean, green and ethical' animal production.

However, some of the animals that are worm-resistant develop 'hypersensitivity diarrhoea' in response to the few worms they still carry. To understand the cause of hypersensitivity diarrhoea, it is necessary to consider molecular and cellular components of the immune system that are directly or indirectly involved in the response to infection with helminths.

It has recently become clear that microRNAs, a class of non-coding RNAs, play a pivotal role in post-transcriptional gene

regulation of cytokine gene expression and immune cell differentiation. In this PhD research, Shamshad will investigate the roles of microRNAs in development of hypersensitivity diarrhoea in sheep that are genetically resistant to worm infection, focusing on the expression of microRNAs by both host and parasite.

The research will test whether the expressions of host microRNAs can be used as biomarkers and targets in the genetic selection program. We will study two parasite species, *Trichostrongylus colubriformis* and *Teladorsagia circumcincta*, during their larval and adult stages, and investigate their role in the modulation of the host's immune response.

A multifaceted approach will be used, including a variety of methods for microRNA profiling of host and parasite. This research will create a list of differentially expressed host microRNAs, which could be an additional tool for selection for worm resistance and for screening populations. In addition, parasite microRNAs have potential as biomarkers for early diagnosis of helminth infection and will lay a foundation for further investigation into helminth-associated diarrhoea.

This research is supported by University of Agriculture Faisalabad, Pakistan.

3: PhD candidate Shamshad Ul Hassan is investigating molecular and cellular components of the ovine immune system that are involved in the response to worm infection. Photo: Prapawan Sawasdee.



4

Variability in nutritive values, methane production and fermentability of *M. paradisiaca* and *P. guajava*

Project team: Professor Philip Vercoe¹ (leader; philip.vercoe@uwa.edu.au), Ms Amriana Hifizah¹ (PhD candidate), Assistant Professor Zoey Durmic¹, Professor Graeme Martin¹

Collaborating organisations: ¹UWA; Tass 1 Trees Nursery Farm.

Reducing livestock methane emissions would reduce the environmental footprint and feed costs of livestock enterprises. To achieve this, we are screening forages that have potential to reduce ruminants' methane (CH₄) emissions, with a focus on agricultural waste and by-products. Previously, we assessed 20 alternative feed sources in Indonesia and found four that produce CH₄ while retaining good fermentability: *Psidium guajava* (guava), *Musa paradisiaca* (banana), *Annona muricata* (soursop), and *Arachis hypogaea* (peanut). In this project, we have focused on banana and guava to determine variation in their nutritive value, methane production and fermentability.

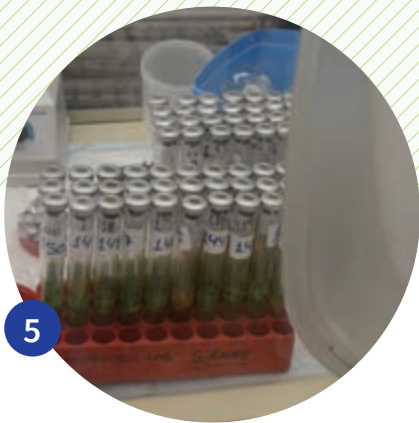
In 2017, we found sources of guava and banana in WA so have been investigating variation across seasons, among varieties within species, and among parts of the plant, using rumen simulations *in vitro*. Nutritive values differed among individual trees, parts of the tree, and varieties of *M.*

paradisiaca and *P. guajava* (all trees were supplied by Tass 1 trees Nursery Farm). The best anti-methanogenic candidates for further testing in mixed diets are *M. paradisiaca* variety William Cavendish and *P. guajava* variety Mexican. As a positive control, we used *Leucaena* because it is used in Indonesia as a basal diet for small ruminants. Our *Leucaena* data from Indonesia shows that, regardless of its high crude protein content, it was less fermentable in the rumen system than *M. paradisiaca*. For CH₄ production, *Leucaena* and *M. paradisiaca* were comparable, although the lowest CH₄ emissions arose from fermentation of *P. guajava*.

We are now preparing to test Australian *Leucaena* (in partnerships with DPIRD) in mixes with *M. paradisiaca* variety William Cavendish and *P. guajava* variety Mexican. This will allow us to determine the best proportions, in terms of safety and benefit, before we feed them to animals.

This research is supported by LPDP, Indonesia Endowment Fund for Education

4: PhD candidate Amriana Hifizah preparing samples for the measurement of volatile fatty acids and ammonia, two factors used to assess fermentability.



In vitro fermentation of industry by-products

Project team: Assistant Professor Zoey Durmic (leader; zoey.durmic@uwa.edu.au), Dr Joy Vadhanabhuti, Dr Bidhyt Banik, Mr Hatem Al-Khazraji

Wilmar BioEthanol is a leading Australian producer of ethanol products, derived from sugar cane or its by-product molasses. During the production process, significant amounts of various industry by-products are generated that are rich in energy and nutrients. These can be fed to animals to provide a cost effective, environmentally sustainable, waste management solution, as well as providing multiple benefits in animal health and production. However, there is little published data and structured studies to support any advantageous effect of these additives in animal production, in particular on rumen fermentation.

The aim of the current project was to improve knowledge on the effect of these by-products in regards to beef rumen productivity and health, and subsequent greenhouse gas emissions. To date, we have conducted four *in vitro* batch fermentation experiments and identified some promising candidates that can promote rumen function

In the next phase we will use the ‘artificial rumen’ to confirm the persistency of the effect over time and in a system that more resembles an animal.

This research is supported by Wilmar Bioethanol Australia Pty Ltd.

5: Bioethanol by-products being tested in the lab. Photo: Zoey Durmic.



How do essential oil compounds reduce methanogenesis?

Project team: Professor Philip Vercoe (leader; philip.vercoe@uwa.edu.au), Professor Graeme Martin, Dr Parwinder Kaur, Assistant Professor Zoey Durmic, Dr Joy Vadhanabhuti and Mr Muhammad Shoaib Khan (PhD candidate).

Essential oils are important secondary plant compounds that have been shown to have anti-methanogenic effects in the rumen. This research is exploring the mechanism of action(s) of these compounds through metagenomics and bioinformatics. It will focus on the effects on rumen microbial gene expression and also the changes in methanogens and ruminal bacterial populations when they are exposed to essential oil compounds.

Methane emissions from livestock enteric fermentation accounts for about ten per cent of Australia’s total greenhouse gas emissions. Methane is produced by a specialised group of gut microbes that reside in the rumen, called methanogens. While it has been shown that bioactive secondary plant compounds – including essential oils – can reduce methane production, their mechanisms of action are unknown.

By identifying these mechanisms, this work could help identify better strategies for mitigating methane emission from ruminants. Future markets for ruminant products will be dependent on improving productivity and reducing the industry’s environmental footprint.

This research is supported by University of Agriculture Faisalabad, Pakistan.

6: Preparing samples for DNA and RNA extraction taken from *in vitro* batch culture fermentation. Photo: Amriana Hifizah.



Rumen epithelial mitochondrial contents could help identify more efficient sheep

Project team: Dr Jude Bond¹ (leader; jude.bond@dpi.nsw.gov.au), Professor Philip Vercoe², Professor Graeme Martin², Dr Hutton Oddy¹, Dr Brian Dalrymple^{2,3} (brian.dalrymple@uwa.edu.au), Dr Nicholas Hudson⁴, Mr Umair Hassan² (PhD candidate).

Collaborating organisations: ¹NSWDPI; ²UWA; ³CSIRO; ⁴UQ

This project aims to help reduce methane emissions from sheep by improving the understanding of rumen mitochondrial activity and genetics.

The rumen plays an important role in feed efficiency and methane production in sheep. It is the main site for microbial fermentation, feed digestion and production of short-chain fatty acids (SCFAs), which are the main energy source in ruminants. The SCFAs are mainly absorbed from the rumen and metabolized in the rumen epithelium, liver and peripheral tissues. They are absorbed by simple diffusion and protein mediated transport. Ketogenic enzymes in mitochondria play a crucial role in the metabolism of SCFAs to ketone bodies, another important source of energy within the body. Differences in the ability of the rumen epithelium to absorb and metabolize SCFAs should be reflected in higher expression of genes involved in their absorption and metabolism.

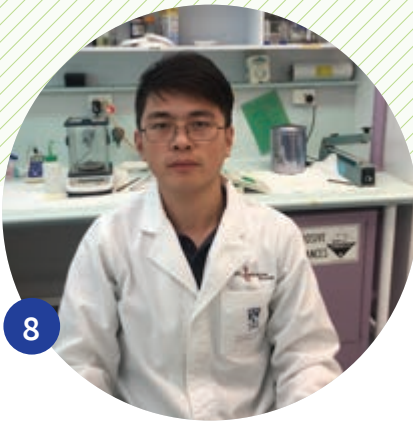
The rumen is also the principal source of methane, and methane emission from ruminant livestock contribute significantly to the environmental footprint of agriculture. More than 87 per cent of the methane produced by sheep has been estimated to be derived from the rumen. Methane emissions also represent a loss of between 7-12 per cent of gross energy in sheep. Reducing methane emission would provide the dual benefits of improving energy utilisation in sheep and reducing their greenhouse gas emission. Understanding the physiological and genetic basis for why animals differ in methane production will be key to using genetic selection to reduce methane emissions. Mitochondria

are a critical component of epithelial cells, and are likely to be involved in the relationship between methane emission and efficiency. Mitochondria are crucial to many cellular metabolic pathways because their main role is to provide energy in the form of ATP via oxidative phosphorylation. Differences in the number, structure and function of mitochondria among animal cells and tissues reflect their responses to energy needs. Just as the energy demands of cells can vary during development and differentiation, and in response to physiological and environmental alterations, the number of mitochondria can also vary through complex and finely regulated processes. It is therefore possible that the mitochondrial contents (defined as the number of mitochondria in a cell) and mitochondrial gene expression in the rumen epithelial cells will be linked to metabolically efficient animals and be a useful tool for identifying those animals in the future.

The study will determine relationships between protein abundance, gene expression and mitochondrial content in the rumen epithelium and different phenotypes in sheep. These phenotypic relationships will be used to identify regions of the genome, or genes, that account for differences in digestive function and characteristics of rumen anatomy. They will be used as cellular markers for selection programs to reduce methane (CH₄) emissions and improve productivity. If they are associated with lowering methane emissions, they will provide the dual benefits of improving feed use efficiency and reducing greenhouse gas emissions. Producers will benefit through reduced feed costs and through rewards via carbon market schemes.

This research is supported by MLA and University of Agriculture Faisalabad, Pakistan.

7: PhD candidate Umair Hassan is investigating the relationships between protein abundance, gene expression and mitochondrial content in the rumen epithelium and different phenotypes in sheep.



Gene polymorphisms in relation to temperament and production in sheep

Project team: Mr Luoyang Ding (PhD candidate; luoyang.ding@research.uwa.edu.au), Associate Professor Dominique Blache, Professor Shane Maloney, A/Professor Mengzhi Wang, Associate Professor Jennifer Rodger

Increasing global population and living standards is increasing the consumption of animal protein and the demand for meat quality. Semi-intensive or intensive production systems offer the opportunity to produce more than other systems because they can optimise the fattening, health, and meat quality of young livestock. However, intensive systems can be taxing because livestock are exposed to new environments (high temperature, increased human contact and higher stocking density). In sheep, stress compromises production efficiency, animal health and meat quality.

Luoyang will study how the temperament traits reflect an animals' ability to adapt to stress. Luoyang Ding completed a Master in Animal Science at Yangzhou University and started his PhD in September 2017 under a China Scholarship Council-The University of Western Australia Joint Scholarship.

Sheep phenotypically selected for low responses to social stressors (calm sheep) are less reactive to stressors and are able to reproduce and produce better when fed a maintenance diet than sheep that are selected for a high response (nervous sheep). Recently, close correlations between quantitative trait loci, single nucleotide polymorphisms, and behavioural traits have been identified. The phenotypic and genetic heritability of temperament traits have been measured in both Merino and Corriedale sheep and are high enough to lead to genetic improvement. In this project, Luoyang will identify new polymorphisms related to temperament and test their effect on growth, meat quality, and welfare. Luoyang will test the importance of central pathways that are affected by these polymorphisms on growth, meat production, and temperament.

8: Luoyang Ding is investigating how temperament traits reflect an animal's ability to adapt to stress. Photo: Luoyang Ding.



Determining the importance of a nest to laying Pekin ducks

Project team: Ms Lorelle Barrett (PhD candidate; lorelle.barrett@research.uwa.edu.au); Associate Professor Dominique Blache, Professor Shane Maloney; Dr Irek Malecki

Lorelle suspended her candidature in 2017 to take up a fixed term position lecturing in animal husbandry and health at Unitec Institute of Technology, Auckland, New Zealand. She recommenced work on her thesis at the end of 2017, and is now working towards completion, in conjunction with part-time work in clinical veterinary practice in New Zealand.

A paper entitled 'Differences in pre-laying behaviour between floor-laying and nest-laying Pekin ducks' has been submitted for review to the Journal of Applied Animal Welfare Science. She has concluded the analysis of video footage of ducks in a behavioural demand unit. The results show that ducks are able to learn to use a behavioural demand testing unit designed by Lorelle based on the morphological and behavioural characteristics of Pekin ducks. Lorelle has demonstrated that female ducks are highly motivated to use the nest box to lay eggs, and that the ducks prefer substrates that can be manipulated to those that cannot. Lorelle is planning to submit her thesis in 2018 and she expects to publish four papers out of her work. Lorelle's thesis is the first comprehensive work aiming at understanding the motivation of female ducks to use nest boxes. Her results should affect the design of laying barns.

9: A duck exiting through the push-door of a specially designed behavioural demand unit during training. Photo: Lorelle Barrett.



Castration methods and welfare of alpacas – Towards an appropriate solution

Project team: Associate Professor Dominique Blache (leader; dominique.blache@uwa.edu.au), Professor Shane Maloney and Dr Amin Mugerá

Castration is an important component of the on-farm management of male alpacas in Australia, because it decreases aggression towards other alpacas and humans, and improves the herd's economic value, since wethers can be sold as guard animals, for fleece production, or used in the evolving alpaca meat industry. However, there has been no standard method to castrate alpacas that could be widely adopted and recommended to veterinarians or alpaca producers.

Our project aimed to investigate and validate standard methods of castration for alpacas that would meet both industry constraints and future animal welfare standards.

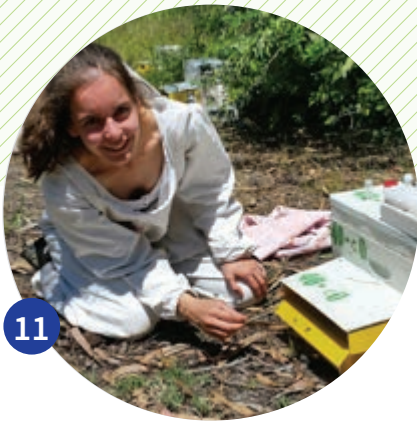
We initially consulted extensively with industry stakeholders, using an online survey and focused discussions with an expert panel. Based on these consultations, we focused on methods of castration (surgical and mechanical), pain management strategies, and the possibility of producers performing castrations.

We tested the efficiency of 1) meloxicam delivered via an oral trans-mucosal (OTM) route in combination with ketamine and xylazine during surgical castration, 2) meloxicam OTM alone or with addition of Tri-solfen® during surgical castration, 3) meloxicam OTM alone during mechanical castration, and 4) oral sedative/analgesic in combination with oral meloxicam. In all experiments welfare was measured using visual pain scoring, behavioural observations, balance testing, and cortisol secretion. All experiments followed the same sampling protocol over two weeks. The animals were monitored for up to ten weeks following mechanical castration.

We compared the results to the best strategy available in terms of welfare. The results showed that meloxicam OTM is a good analgesic in alpacas and is not too expensive. Sedation in combination with meloxicam OTM gave the best pain management following surgical castration, and the combination of oral meloxicam and Tri-solfen® offers an economical and acceptable solution to trained lay operators. From our research, we recommended two options that are defensible on welfare grounds. The best option is surgical castration by a veterinarian using full anaesthesia and analgesia with a combination of oral meloxicam in addition to a mixture of ketamine and xylazine. This could be adopted immediately by the industry. A second defensible option involves surgical castration conducted by a non-veterinarian after the administration of oral meloxicam followed by Tri-Solfen®. This would require adequate training of people to perform castrations, and we recommended a training course be created to enable this. We strongly recommended against the use of mechanical castration and found that testicular size is the best indicator of the preferred method of castration.

This research is supported by RIRDC.

10: Castrated alpacas, like this white Huacaya wether, show less aggression and are more valuable than non-castrated males. Photo Dominique Blache.



11

Crop pollination efficiency by honeybees (*Apis mellifera*) and the effects of native and non-native floral sources

Project team: Ms Madlen Kratz¹ (PhD candidate; kratzm01@student.uwa.edu.au), Dr Boris Baer¹, Dr Rob Manning³, Associate Professor Dominique Blache¹, Professor Kingsley Dixon²

Collaborating organisations: ¹UWA; ²Curtin University; ³Australian Natural Biotechnology

This project aims to quantify the effects of honeybee nutrition, specifically the effect of native pollen (coastal bush flowers, redgum [*Corymbia calophylla*]) and jarrah (*Eucalyptus marginata*) versus non-native (canola [*Brassica napus*]) pollen on honey bee health and pollination efficiency.

The research is part of Madlen Kratz' PhD studies. Madlen completed experiments in the laboratory, the UWA bee facility and in the field to: 1) identify whether honeybees choose different

food sources when infected with the common gut parasite *Nosema apis*, 2) quantify the effects of these food sources on honeybee longevity, and 3) measure the effects on longevity and pollination capacity of honeybees reared on different honey and pollen sources in a commercial environment.

Madlen has collected a few thousand bee samples and has started analysing them. She has established a strong collaboration with ChemCentre to analyse the composition of food sources and bees. Madlen was a semi-finalist in the WA Farmers and Rural Bank Agriculture Award as part of the 2017 Western Australian Young Achiever Awards.

11: PhD Candidate Madlen Kratz aims to quantify the effect of honeybee nutrition on honeybee health and pollination efficiency.



3

Water for Food Production

Theme Leaders

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The Water for Food Production theme focuses on improved efficiencies in irrigated agriculture and better use of finite water resources to meet the food needs of an increasing world population. Thirty-seven per cent of the world's total land area is available for agricultural production, approximately twenty per cent of which is irrigated. Irrigated agriculture provides forty per cent of the world's food and can give crop yields two to four times greater than rain-fed agriculture.

Western Australia is investing in horticulture development and building capacity in providing irrigated agriculture for local and international markets. The development of such irrigation schemes requires fit-for-purpose delivery systems that are economically and technically efficient, optimise on-farm water use for maximum return, and minimise detrimental impacts on the local environment.

In particular, minimisation of detrimental effects needs to focus on management of irrigation return water to the

environment so as to minimise downstream water-quality issues and subsequent risks to public health. The rapid emergence of readily available sensing technology has created new opportunities for informing water-management decision-making, allowing us to identify sustainable solutions.

In dryland agriculture yield improvements can be achieved through water conservation, requiring an understanding of how direct evaporative losses and deep drainage losses below the rootzone can be minimised.

The Water for Food Production theme undertakes research to understand where water goes after it rains, how much is available to plants and how current water losses can be reduced. This forms part of more widespread research on water balances and irrigation modelling, and environmental sensing and assessment, with a strong focus on industry collaboration and engagement, postgraduate training and technology exchange.



1

Impetus for adoption of tube-well irrigation technology under depleting groundwater resources in Punjabi, Pakistan

Project team: Dr Amin Mugera¹ (leader; amin.mugera@uwa.edu.au), Dr Muhammad Arif Watto^{1,2}, Dr Muhammad Mudasar Saqab⁴ and Professor Ross Kingwell³

Collaborating organisations: ¹UWA, ²University of Agriculture, Faisalabad, Pakistan, ³AEGIC, ⁴University College Dublin, Ireland

Groundwater resources are crucial in sustaining agro-ecosystems and ensuring food security in many parts of the world. However, the sustainability of groundwater resources is subject to a number of challenges, including over-extraction, deterioration in quality, and vulnerability to the impacts of climate change and population growth. Given the current state of groundwater resources in Pakistan, policymakers seek to manage groundwater resources by limiting groundwater extraction. However, achieving this goal at a national scale is not easy. To design effective groundwater policies, policymakers and administrators often want to understand the motivation of local farmers to adopting tube-well irrigation technology.

This research project investigated smallholder farmers' decisions to adopt tube-well technology in the face of dwindling groundwater resources and falling water tables in the Punjab province, Pakistan. Analyses were based on cross-sectional survey data of 200 rural households from the arid to semi-arid regions of Punjab. The study found that farmers will adopt tube-well technology in pursuit of reliable irrigation water supplies to hedge against production risks, but not against the risk associated with unfavourable extreme events (downside risk) such as total crop failure. This suggests that the adoption decision is influenced by the expected long-term rather than the short-term benefits. There is a need to regulate groundwater resource exploitation by requiring the use of tube-well technology to be accompanied by irrigation water efficient techniques and technologies.

1: Tube-well in Punjab, Pakistan



2

International Water Centre's Master of Integrated Water Management

Project team: Adjunct Professor Jeff Camkin (leader; jeff.camkin@uwa.edu.au), Adjunct Professor Susana Neto

Each year the IOA hosts students from the Brisbane-based International Water Centre Master of Integrated Water Management course when they visit Perth to undertake the elective, Water and Agricultural Landscapes, coordinated by Professors Susana Neto and Jeff Camkin.

In December 2017 a small but diverse group of participants from Antigua and Barbuda, Australia, Paraguay, Philippines and the USA visited Perth for an eight-day intensive session at UWA. The participants were welcomed by IOA Director Professor Kadambot Siddique, with a farewell by UWA Pro Vice Chancellor, Research, Professor Peter Davies. In between, the participants were exposed to co-learning methodology adapted to the needs of each participant by framing content and discussions around their personal learning objectives.

In sharing their backgrounds, education and professional experiences, each participant made a substantial contribution to the learning of their peers. This was balanced with interactive lectures from Professor Siddique, Dr John Ruprecht, Dr Ed Barrett-Lennard and Professor Graeme Martin.

Two excellent field trips to the Gngangara mound and WA Wheatbelt were coordinated by Rob Karelse from the WA Department of Water and Environment and Ken Flower, respectively, provided practical insights into water management issues in WA.

The course coordinators rounded out the programme with several interlinked workshops and reflection sessions. All of this fed into final presentations on their last day when they shared their new ideas for improving the management of water and agricultural landscapes.

More details on the Water and Agricultural Landscapes module, and the Master of Integrated Water Management, are available at watercentre.org/master-of-integrated-water-management/.

2: Master of Integrated Water Management Class of 2017.



Determining design criteria to maximise nutrient removal by vertical flow-through wetlands

Project team: Ms Rasha Al-Saedi (PhD Candidate; 21456205@student.uwa.edu.au), Adjunct Professor Keith Smettem, Hackett Professor Kadambot Siddique, Professor Andy Fourie

Constructed wetlands (CWs) are a natural alternative to traditional methods of wastewater treatment. In Europe, they have become a focus of study in the past few decades because they confer outstanding benefits of small footprint, low construction and maintenance costs, and low energy requirements. In the field of wastewater treatment, there are generally two main types of CWs: free surface and subsurface flow systems. Subsurface flow wetlands can also be classified into two categories depending on the direction of flow: horizontal flow constructed wetlands (HFCWs) and vertical flow constructed wetlands (VFCWs).

A laboratory scale vertical flow constructed wetland (VFCW) system was designed to investigate how denitrification rates could be affected by improving substrate conditions for denitrifying bacteria. There is some evidence that provision of an external organic carbon source, enhancement of the microbial population via addition of activated sludge and an appropriate filter medium may have positive impacts on denitrification rates. To more thoroughly investigate these factors, we undertook controlled laboratory experiments using laboratory scale constructed wetlands.

In the first experiment two different organic carbon sources (sucrose and ethanol) were added to the wetland system under saturated conditions and subsequent denitrification rates were compared to controls with no added organic carbon. Experiments were conducted with and without addition of activated sludge. Interestingly, results showed that only the ethanol treatment significantly enhanced the rate of denitrification.

In the second experiment, each column was divided into two zones: anaerobic and anoxic in order to assess the denitrification processes in each zone. Sampling was carried out every seven days over the continuous operation of 182 days to analyse the N compound concentrations. Overall, no major differences were observed between the anoxic and the anaerobic zones in terms of nitrogen compound removal, with both zones achieving high efficiencies of N removal (to acceptable wastewater standards within the experimental period). From a practical perspective, operation of the wetland as a fully saturated system is advantageous because mass removal per unit volume is proportional to the volumetric water content, which is seven times greater in the saturated zone compared to the unsaturated zone.

Over the past two decades, clogging of pore spaces has been widely recognised as an operational issue in subsurface flow treatment wetlands, with many of the designed wetlands suffering from clogging problems. This operational problem has led to increased research interest on how to control or prevent the occurrence of clogging.

We used our laboratory wetland systems to investigate using coarse sand as a main support medium with an initial flow rate of 0.208 m³/d. The aim was to test if the biodegradable organic substrates used in the first experiment (sucrose as a sugar source and ethanol as an alcohol source) led to clogging over time. This experiment is still underway, with eighty per cent of the laboratory work already completed. Early results indicate that clogging is occurring faster in the wetlands with the added carbon sources, but even the controls are exhibiting reduced flow rates over time.

This research was supported by the Iraqi Government's Higher Committee for Education Development Scholarship.

3: Experimental set-up of vertical flow constructed wetlands. Photo: Rasha Al-Saedi





4

Food Quality and Human Health

Theme leaders



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The health attributes of foods are an important driver for food choices and UWA has strengths in developing and validating healthy foods and food ingredients.

The Food Quality and Human Health research theme is leading towards developing the connection between the composition and quality of whole foods and dietary health, as well as improved strategies for breeding, production and manufacture. The research will deliver scientifically validated evidence for the promotion of new foods, as well as significant added value to agricultural industries.

The theme integrates complementary skills, knowledge and activities across disciplines at UWA, in collaboration with researchers from within and outside Western Australia, and relevant industries and their representative bodies.



Genomic research to improve the value of the narrow-leaved lupin (*Lupinus angustifolius* L.) grain

Project team: Ms Karen Frick^{1,2} (PhD Candidate; karen.frick@csiro.au), Dr Rhonda Foley², Dr Lars Kamphuis², Hackett Professor Kadambot Siddique¹

Collaborating organisations: ¹UWA; ²CSIRO Agriculture and Food

Narrow-leaved lupin is a major grain legume crop in Australia that has recently gained recognition as a human health food. However, levels of the toxic quinolizidine alkaloids produced by the crop sometimes exceed the industry limit to be fit for human and animal consumption. Mechanisms of quinolizidine alkaloid biosynthesis, transport, and responses of these to environmental conditions are poorly understood.

In 2017, we assessed the response of grain alkaloid content to abiotic and biotic stresses often imposed on a lupin crop. We identified that both drought and higher temperature can increase lupin grain alkaloid levels, however this effect is dependent on the cultivar; out of three cultivars assessed, one cultivar responded to drought, while another responded to higher temperature, with no significant combined effect of both drought and higher temperature for either cultivar. The grain alkaloid levels of the third cultivar did not respond to these stresses, providing an opportunity for breeders to select lines that do not change alkaloid content under drought and higher temperature conditions.

We assessed the effect of aphid predation on grain alkaloid content in lupin. Despite these alkaloids playing a role in the defence of the plant against insect predators and the hypothesis that their biosynthesis may increase in response to insect attack, aphid predation did not affect grain alkaloid content in either aphid-resistant or susceptible cultivars.

We have also made progress towards identifying a major domestication gene in narrow-leaved lupin, *iucundus*, which affects alkaloid content and has been imperative in the development of narrow-leaved lupin as a food and feed crop. Identifying this gene will allow for the recessive low-alkaloid allele to be easily tracked in breeding programs, to facilitate the introgression of genetic material from wild high-alkaloid accessions, while selecting for low alkaloid content.

This research will assist in the production of improved narrow-leaved lupin cultivars, with safe grain alkaloid levels that are stable across the environmental stresses that the crop endures during a growing season. This serves to enhance the quality and value of a major grain legume crop and encourage its use in sustainable agricultural practices.

This research is supported by UWA, GRDC and CSIRO Agriculture and Food.

1: Narrow-leaved lupin grown under controlled conditions identifies that drought and higher temperature can increase grain alkaloid levels. Photo: Karen Frick.



Effects of lupin-containing foods on blood sugar levels and blood pressure in type 2 diabetes

Project team: Dr Natalie Ward¹ (leader; natalie.ward@uwa.edu.au), Professor Jonathan Hodgson⁴, Professor Trevor Mori², Associate Professor Stuart Johnson³, Dr Carolyn Williams¹, A/Professor Seng Khee Gan¹, E/Professor Lawrence Beilin¹

Collaborating organisations: ¹UWA; ²Royal Perth Hospital Medical Research Foundation; ³Curtin University; ⁴Edith Cowan University; ⁵Sanitarium Health and Wellbeing Company; ⁶Il Granino Bakery; ⁷Otaway Pasta Company

Type 2 diabetes may affect as many as 3.5 million Australians. Although there is a strong genetic link, diet and lifestyle also play important roles in the development of type 2 diabetes. Early management of type 2 diabetes through diet and lifestyle change can help to maintain blood glucose levels within normal ranges, and beneficially impact other cardiovascular disease risk factors such as high blood pressure.

Cardiovascular disease is the primary cause of death in people with type 2 diabetes, and type 2 diabetes and hypertension often co-exist, increasing risk of cardiovascular disease and possibly contributing to cognitive impairment. Lupin is a novel food ingredient that is rich in fibre and protein and contains negligible sugar and starch (glycaemic carbohydrate). There is growing evidence that foods containing lupin could make a positive contribution towards the management of type 2 diabetes via their low glycaemic index.

The primary aim of our study is to determine whether regular consumption of lupin-containing food products can improve short-term glycaemic control and lower blood pressure in type 2 diabetic participants. Secondary aims are to determine whether regular consumption of lupin-containing food products can improve cognitive domains of attention and working memory in type 2 diabetic participants.

This project is directed at the earlier stages of diabetes, that is, moderate to well-controlled diabetic participants, where better blood glucose management could slow progression and reduce the need for additional medication or medical intervention.

In 2017, all study participants completed the study (screening and recruitment began in June 2015). In total, 33 participants were randomised, with 17 completing both treatment arms, five completing one treatment arm and 11 withdrawing from the study. Data entry on participants' home blood glucose and home blood pressure recordings begun at the end of 2017 and is expected to be completed in early 2018, with subsequent biological sample analysis, statistical analysis and preparation of manuscripts to be finalised in mid-to-late 2018.

Additional measurements of the effects of lupin-containing foods on microbiome composition and functionality have also been included as study endpoints. This is particularly relevant given the role of the microbiome in cardiometabolic diseases such as type 2 diabetes and overall host health, as well as the ability of diet to strategically target and beneficially alter microbiome composition. This will provide insight into the potential beneficial role of lupin-containing foods in managing type 2 diabetes.

This research is supported by Royal Perth Hospital Medical Research Foundation and Sanitarium Health and Wellbeing Company.

2: There is growing evidence that incorporating lupin into everyday foods could make a positive contribution towards the management of type 2 diabetes via their low glycaemic index.



Development of nutritionally enhanced apples

Project team: Professor Jonathan Hodgson² (jonathan.hodgson@ecu.edu.au); Dr Michael Considine^{1,3}; W/Professor Tim Mazzaro¹; Dr Catherine Bondonno⁴; Professor Kevin Croft¹; Professor Wallace Cowling¹; Dr Elena Mamouni Limnios¹; Ms Nicola Bondonno¹; Ms Diana Fisher^{2,3}; Dr Fucheng Shan³; Mr Kevin Lacey³; Mr Steele Jacob^{2,3}

Collaborating organisations: ¹UWA; ²Edith Cowan University; ³DPIRD; ⁴Australian National Apple Breeding Program; ⁵Pome West; ⁶Horticulture Innovation Australia; ⁷Fruit West

This research and development program aims to transform the value of Australian-bred apples. The goal is to gather evidence to support the marketing and consumption of newly released apple varieties with elite levels of flavonoids.

Our hypothesis is that particular flavonoids present at high levels in some apples contribute significantly to the nutritional quality of fresh apples. Flavonoids are compounds present in plant foods, some of which are likely to provide a positive contribution to the health of the vascular system. The flavonoid contents of apples vary by several orders of magnitude between varieties. We previously showed significant health benefits of a flavonoid-rich apple, which grabbed industry attention. During 2017 progress has been made on three key aspects of this research program.

First, we expanded the screening program and have now screened over 100 selections from the Australian National Apple Breeding Program, as well as several commercial varieties. In parallel, the genetic information on these selections has been gathered, and is currently being linked

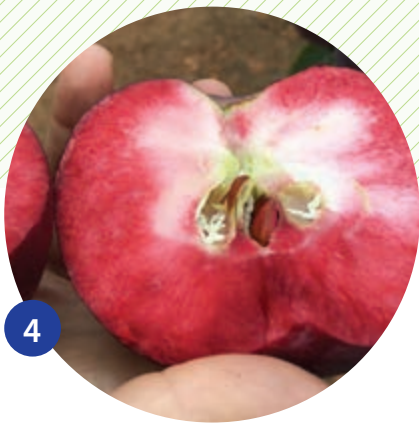
with the flavonoid content data. We have also measured the flavonoid content of apples before and after long-term storage to establish the stability of flavonoids during storage. This knowledge will provide a platform to select apples, assist breeding, and promote new flavonoid-rich apple varieties. The first manuscripts describing the results of these activities will be completed and published in 2018.

Second, we completed a human intervention study to investigate if consumption of high flavonoid apples can result in acute and sustained benefits on measures of vascular health. The study included 30 participants. The first of two manuscripts describing the results of this study is now published. A second manuscript will be written during 2018.

Finally, during 2017 funding was sought and obtained to conduct a follow-up trial to investigate the short-term effects of a high-flavonoid apple. As part of the Australian National Apple Breeding Program a new high flavonoid apple – the Bravo™ apple – was released in 2017. Our trial will establish if the regular consumption of one Bravo™ apple each day can improve measures of vascular health. The study will be completed by the end of 2018.

This research is supported by Australian National Apple Breeding Program, DPIRD, Horticulture Innovation Australia, Pome West, and Fruit West.

3: As part of the Australian National Apple Breeding Program a new high flavonoid apple – the Bravo™ apple – was released in 2017.



Markers, Markets and Validated Nutritional Qualities of Australian Apples

Project Team: Dr Michael Considine^{1,3} (leader; michael.considine@uwa.edu.au); Mr Steele Jacob^{2,3}; Mr Kevin Lacey^{2,3}; Ms Diana Fisher^{2,3}; Kristen Brodison^{2,3}; Professor Wallace Cowling¹; Dr Matthew Nelson^{1,7}; Professor Jonathan Hodsgon⁴; Professor Kevin Croft¹; Dr Catherine Bondonno⁴; Dr Nicola Bondonno¹; Dr Satish Kumar⁶; Dr Andrew Granger¹; W/Professor Tim Mazzarol¹; Professor Geoff Soutar¹; Dr Elena Mamouni Limnios¹.

Collaborating organisations: ¹UWA; ²Australian National Apple Breeding Program; ³Department of Primary Industries and Regional Development; ⁴Edith Cowan University; ⁵Fruit West; ⁶Plant and Food Research (Australia, New Zealand); ⁷Kew Royal Botanic Gardens

This project directly interfaces with ‘Development of Nutritionally Enhanced Apples’. As described, the research has shown significant improvements to cardiovascular health from the consumption of apples. In particular, we have solid evidence that the flavonoids in apples are important for these benefits.

This matters because the market share of fresh Australian apples (and other fresh fruit) has been spectacularly eroded by the rising consumption of ‘functional foods’, which market effectively on nutrient or phytonutrient content, particularly the ‘antioxidant’ content. The debate about antioxidants can wait for another day, but the fact is, how many of these products are clinically proven to improve health? And what can the apple industry do about it?

This project – or portfolio of projects – addresses the three component strategies to improve consumption and value of Australian-bred apples:

- Validate the nutritional benefits (Development of Nutritionally Enhanced Apples).
- Accelerate breeding for elite (‘healthier’) apples.
- Define marketing pathways for novel varieties.

Here we outline progress on subproject 2. In 2017 we completed screening for flavonoid content in over 100 apple varieties and breeding selections from the Australian National Apple Breeding Program (ANABP). This showed enormous genetic variation in flavonoid content. Importantly, we then

conducted pedigree analysis (i.e. a family tree) to understand how flavonoids are transferred through breeding. This showed that some flavonoids are highly heritable, and some varieties are likely to be very good parents for transferring these traits. This provides strong proof of concept that we can selectively breed for apples richer in flavonoid content.

Knowing that we can selectively breed, the next step is how to integrate this into the ANABP. This question is the subject of a pending application for a large national grant from the Australian Research Council, with partners and from ANABP/DPIRD and Plant and Food Research (Aust/NZ). That project will extend the pedigree analysis to 1000 varieties, generating decision-making tools to design future crosses. It will deploy cutting edge genomic techniques to define the genetic basis of flavonoid content, generating molecular markers that can be used to select (or reject) the progeny of crosses for high-flavonoid content at the seedling stage, which will massively increase efficiencies in time and space. It will then go on to provide robust scientific evidence of the genetic control, in doing so contributing to the training of young scientists in perennial fruit genetics, molecular biology, and breeding. And importantly, these outcomes will be implemented in real-time in the national breeding program.

Subproject 3 meanwhile, is progressing through the work of Professor Mazzarol and Professor Soutar, who are building on their earlier work to define the market pathways in parallel to subprojects 1 and 2.

Together, these subprojects will realise a longer term and widely held vision to use molecular technologies to increase the speed and efficiencies of breeding new, high-value apples and underpin domestic and export growth. All through conventional breeding, and through honestly promoting the natural health benefits of fresh whole foods.

This research is supported by Pome West; Australian National Apple Breeding Program; DPRID; HIA

4: Advanced selections and dirty boots. Dr Considine with the ANABP team, admiring one of the advanced selections in the breeding program at Manjimup.



5

Oxygen Signalling in Grapevine Bud Dormancy

Project Team: Dr Michael Considine^{1,2} (leader; michael.considine@uwa.edu.au); Dr Santiago Signorelli¹; Dr Patricia Agudelo-Romero¹; Professor Christine Foyer^{1,3}; E/ Professor John Considine¹; Dr Daniel Gibbs⁴; Dr Karlia Meitha¹; Ms Dina Hermawaty¹; Ms Yazhini Velappan¹; Ms Juwita Dewi¹; Mr Keith Mugford⁵; Mr Alex Coultas⁵

Collaborating organisations: ¹UWA; ²DPIRD; ³University of Leeds; ⁴University of Birmingham; ⁵Moss Wood Wines

The overwhelming majority of fruit and nut crops are borne on woody perennial trees. The most economically important is grapevine, which is grown in over 100 countries and contributes to fresh and dried fruit, beverage and wine, and nutraceutical industries. Grapevine is deciduous – as are many other fruit and nut trees – but is commercially grown across over 30 ° latitude, from cool-temperate to tropical climates. The vine behaviour and crop cycles vary remarkably over this range, as grapevine is highly dependent on seasonal cues, such as temperature and day length.

This project seeks to understand how seasonal changes in growth are regulated in grapevine. Studying the year-long growth behaviour of grapevine requires multiple years of analysis and a team of researchers including two postdoctoral researchers and four PhD students.

In 2017, Dr Karlia Meitha was awarded her thesis entitled ‘The spatial dynamics and molecular mechanism of oxygen-dependent signalling during bud burst in grapevine’. Meitha’s greatest contributions were defining how oxygen contributes to the course and coordination of bud burst, which is the critical resumption of growth following dormancy in spring.

Three other PhD students also progressed their studies on the topic; Yazhini Velappan, Dina Hermawaty and Juwita Dewi. Master’s student Declan McCauley was also awarded a higher distinction for his thesis on the topic.

This research is supported by Australian Research Council.

5: PhD students Dina Hermawaty (left) and Juwita Dewi (right) collecting material for their studies from the Moss Wood Ribbon Vale vineyard, Margaret River.



5

Engineering Innovations for Food Production

Theme leaders

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The Engineering innovations for food production theme focuses on providing engineering solutions to agriculture for sustainable growth of net farm-yield, reduction of wastage, and minimisation of environmental impact. As we head towards 2050 and face the need to feed 50% more people on fewer resources, food production efficiency will become increasingly important and highly dependent on advances in agricultural engineering (ag-engineering).

This theme brings together ag-engineering-related teaching and research across the whole of UWA, and allows us to respond efficiently to new challenges and opportunities as they arise. A recognisable and identifiable agricultural engineering theme presents extensive opportunities for collaboration between farmers and agricultural machinery manufacturers with IOA in order to undertake research and development (R&D) focused on bringing about commercial innovation.



UWA partners Ausplow Farming Systems to optimise seeding performance

Project team: Dr Andrew Guzzomi¹ (leader; andrew.guzzomi@uwa.edu.au), Professor Graeme Martin¹, Hackett Professor Kadambot Siddique¹, Mr Steven Wainewright¹, Mr John Ryan², Mr Carl Vance², Mr Chris Farmer²

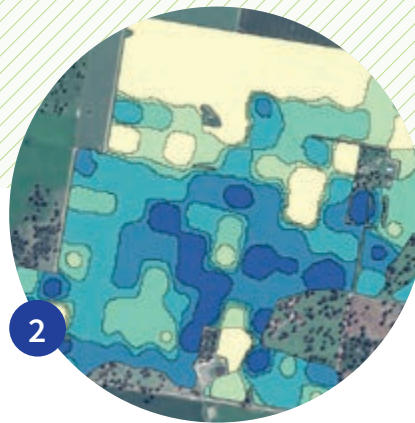
Collaborating organisations: ¹UWA, ²Ausplow Farming Systems

Optimising the performance of machinery is an important means of improving crop yields in the grainbelt of Western Australia. In 2017, UWA entered a research and development partnership with Ausplow Farming Systems to improve crop yields and machine performance. The landscape at UWA Farm Ridgefield is challenging in terms of soil type, obstacles and paddock shape. The partnership with Ausplow will help optimise seeding practices and is a major step forward in transforming Ridgefield, UWA's 1600ha farm near Pingelly, into a farm of the future.

The partnership began in 2017 and will run over three years. Each year, Ausplow will test various configurations of their DBS D260-36 matched to a 6000 litre Drawbar mounted Airseeder for seeding in the wide-ranging landscapes at Ridgefield.

The move toward smaller, more flexible tractor-machine combinations will permit Ridgefield to crop landscapes that at present are inaccessible. Trial plans for 2018 include the conversion of the seeder to liquid fertiliser.

1: Ausplow will test various configurations of their DBS D260-36 matched to a 6000 litre Drawbar mounted Airseeder for seeding. Photo: Ausplow.



Dynamic load project

Project team: Dr Andrew Guzzomi¹ (andrew.guzzomi@uwa.edu.au); Dr Carlo Peressini¹

Collaborating organisations: ¹UWA; Roesner

The Marshall Multispread is an all-purpose fertiliser spreader designed and manufactured in Harvey, WA by Roesner Pty Ltd. The Marshall Multispread is used by Australian farmers to apply granulated fertilisers such as urea and superphosphate, as well soil ameliorants like lime, gypsum, dolomite and manure. Since the early 1980s, over 9500 Multispread units have been manufactured and today the Multispread range is used in all forms of Agriculture, from broadacre cropping through to livestock and horticulture.

Roesner Pty Ltd has developed a mobile app based on Internet of Things (IoT) technology that is integrated with the Multispread machine to set and control the rate of fertiliser applied as the spreader moves across the field. The mobile app can vary the fertiliser application rate across the field according to a prescription map derived from soil samples and historical yield data.

The UWA Agricultural Engineering team worked with Roesner Pty Ltd to combine modelling techniques and current data acquisition approaches to improve the accuracy of real-time adjustments of fertiliser application rates. The algorithm is being incorporated into software and will soon be integrated into the new model App.

This research is supported by Roesners and AusIndustry (Innovation Connections Grant).

2: Example Lime Prescription Map, Field size: 353 ha, application rate range 0 to 3000 kg/ha. Image: Matt Roesner.



Unmanned airborne sensing for detection of improvised threats

Project team: Professor Lorenzo Faraone¹ (leader; lorenzo.faraone@uwa.edu.au), Professor Dilusha Silva¹, Associate Professor Gino Putrino¹, Associate Professor Jarek Antoszewski¹, Associate Professor Mariusz Martyniukhere¹

Collaborating organisations: ¹UWA; Defence Science and Technology Group; Scientific Aerospace; Panorama Synergy Ltd

This project aims to develop a novel airborne drone-based sensing platform for detecting improvised explosives.

The technology will be directly applicable for on-farm crop sensing, and the investigators aim to conduct a demonstration at UWA Ridgefield Farm in 2020.

This project was awarded at the end of 2017, and work will begin early in 2018. Total funding for this project is \$2.9M over three years.

This research is supported by the Australian Department of Defence Next Generation Technologies Fund, under the Counter-Improvised Threats Grand Challenge scheme.

3: A packaged UWA MEMS sensor depicted with a 10c coin for size comparison. Photo: Dilusha Silva.



Sensing solutions for sheep welfare

Project team: Professor Dilusha Silva¹ (leader; dilusha.silva@uwa.edu.au); Associate Professor Gino Putrino¹

Collaborating organisations: ¹UWA; DPIRD

This project assessed sensing solutions for maintaining the welfare of sheep on farms. Specifically, the following two issues were identified in conjunction with DPIRD as the two most important issues facing the sheep industry: (i) Sensing solutions to estimate nutrient value in dry pasture, and (ii) Sensing solutions to detect flystrike in sheep.

A low nutrient content in a sheep's diet may lead to weight loss, low fertility, mortality, increase in risk of disease and poor wool growth. Protein content available in pastures could be estimated through mapping nitrogen content.

Cutaneous myiasis, commonly known as flystrike is the invasion of a sheep's body by parasitic flies and maggots, which eat away at the flesh of the sheep. Flystrike is a welfare risk to sheep and an economic problem to farmers, costing the Australian agricultural industry an estimated \$280 million annually.

This project began in 2017, with three interns working on literature reviews and analysing various sensing options. Design options for practical on-farm sensing solutions are now being developed.

This research is supported by DPIRD through student internships.

4: Lucilia Cuprina which causes 90 per cent of flystrike cases in Australia. Photo: Miranda Kate.



6

Agribusiness Ecosystems



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The agribusiness ecosystem is about the interconnectivity and linkages of agricultural enterprises with each other and also with non-agricultural enterprises in the exchange of goods and services. The essence of the ecosystem is the creation of economic value, which is the focus of every commercial activity.

The term ecosystem has its roots in biology. It represents an interaction of living organism in conjunction with the non-living components of their environment such as water, soil, minerals and air. The ecosystem exists because of the interconnectivity and relationships between and among the components in the system and their implied interdependencies. Therefore, the robustness of an ecosystem will depend on the strength of the bonds and interrelationships of the components or entities in the community.

The same is true with the agribusiness ecosystem. Agribusiness encompasses all the various business enterprises and activities from the supply of farm inputs, on-farm production, manufacturing and processing to distribution, wholesaling and retailing of agricultural produce to the final consumer. All those business enterprises along the value chain are interconnected. The success of any agribusiness firm does not depend only on how efficiently and effectively it is internally managed but also on how it effectively co-opts the complementary capabilities, resources, and knowledge of the network of other firms and institutions in the same industry and beyond. This includes doing business with non-agricultural oriented businesses in banking and insurance among others, and receiving services from government and educational institutions.

The aim of the Agribusiness Ecosystem theme at the UWA Institute of Agriculture is to advance scholarship on socio and economic issues affecting agriculture locally in Western Australia, at national level in Australia, also globally in other developed and developing countries. The team of scholars and professional experts in this theme address issues related to the governance, productivity, profitability and sustainability of agribusiness enterprises and industries by providing innovative policy solutions through research, education, training and capacity building.

Here we provide highlights of research and training activities delivered through the Agribusiness Ecosystem theme in 2017. Our research focus contributes to realisation of the 2030 Agenda of Sustainable Development. Our research provides evidence-based policy on: eradicating poverty and reducing vulnerability to poverty through social protection; eliminating hunger by improving agricultural productivity and food security by investigating factors that enhance adoption of new technology; improving good health and wellbeing by addressing food safety issues in food value chains; conserving the environment by investigating factors that enhance adoption and intensive use of sustainable agricultural practices; and providing quality education and executive training to agribusiness practitioners among others. In this summary of our activity, we also highlight empirical study that has secured Australia's access to lucrative biofuel markets in the European Union.

National mutual economy report

Project team: W/Professor Tim Mazzarol (leader; tim.mazzarol@uwa.edu.au), Dr Elena Mamouni Limnios, W/Professor Geoff Soutar

The UWA Co-operative Enterprise Research Unit (CERU) engaged in several research projects in the 2017 period. First, CERU completed the data collection for the Business Council of Co-operatives and Mutuals (BCCM) annual National Mutual Economy (NME) report. This involved working with the BCCM to identify and update the Australian Co-operative and Mutual Enterprise Index (ACMEI). This tracks the size of the Co-operative and Mutual Enterprise (CME) sector across Australia, identifying the total number, their location, industry sectors, annual financial status, employment and membership statistics. It also examines selected industry sectors and prepares case studies of relevance to the sector as well as analysis of the data to show the growth, decline and performance of the sector.

Second, CERU conducted a study on consumer preferences for the 'Bravo' high flavonoid apples. An online consumer survey was administered to collect data from consumers using a conjoint design. The research study continues into 2018.

Third, CERU undertook a study for the Co-operative Bulk Handling (CBH) Group Ltd to investigate the application of Co-operative Capital Units (CCUs) to a non-distributing (Not-for-Profit) co-operative enterprise. Australian legislation has introduced a special financial instrument known as Co-operative Capital Units (CCUs) with the aim of providing flexibility in raising capital from members and external investors while maintaining member control. CCUs have a role to play in alleviating some of the ownership costs of co-operatives, above and beyond the goal of financing. This research examined the merits of a CCU for a particular type of co-operative structure, the non-distributive co-operative model (NDC). Both debt and equity-type CCUs were considered, examining the purpose these are likely to serve and their structure in terms of ownership, governance, reward and trading mechanisms. In addition to the theoretical analysis, two cases of CCUs issued in WA were analysed in depth. Finally, this research provided a high level overview of the capital structures of NFP cooperatives included in the 2014 World Co-operative Monitor.

Market-securing research: Australian export of canola to the EU

Project team: Professor Ross Kingwell^{1,2} (leader: ross.kingwell@aegic.org.au), Mr Nick Goddard³, Dr Sandra Eady⁴, Dr Tim Grant⁵

Collaborating organisations: ¹AEGIC; ²UWA; ³Australian Oilseed Federation; ⁴CSIRO; ⁵LifeCycles Pty Ltd

This project team collaborated in research that has secured Australia's access to the lucrative European Union (EU) biofuel market. This research will be featured at the CSIRO Ag Catalyst conference in August 2018. The EU is a major market for the export of canola from Australia. Most of the canola grown in Australia is exported to the EU where, due to its non-GM status, it receives a price premium of at least \$30 per tonne. About 70 per cent of Australia's exports of canola to the EU go into the EU biofuel sector as the EU has mandated that at least 10 per cent of all fuels used in the EU transport sector need to be sourced from renewable energy such as canola. However, biofuels made from biomass crops such as canola are only accepted if they provide sufficient savings in greenhouse gas emissions relative to the fossil fuels they replace.

Canola crops only had to meet a 35 per cent emissions saving to be acceptable to the EU biofuel market; but in 2013, the EU announced tighter emission regulations that would come into force on January 2017 (later amended to January 2018). Mr Nick Goodard and Professor Ross Kingwell became aware of this regulation change and realised that unless it could be scientifically shown that emissions associated with canola production in Australia were low by international comparison, canola would no longer be able to be exported to the EU. This would mean loss of the \$30 per tonne premium available in the EU biofuel market and Australian canola would need to be exported to other markets in which no premiums applied.

Research by the CSIRO and LifeCycles Pty Ltd, assisted by AEGIC, the AOF and federal government departments, led to findings that Australia was a source of low emission canola. This research was critical for retaining market access. In late December 2017 the EU formally announced that Australia and its states were acceptable low emission sources of canola and so imports of canola into the EU could continue from January 2018. The research has helped secure Australian exports of canola to the EU, annually worth \$1.5 billion.

This project was supported by DPIRD and the AOF, plus in-kind support from the CSIRO.

1: Most of the canola grown in Australia is exported to the EU.

International grain supply chains

Project team: Professor Ross Kingwell^{1,2}
(leader; ross.kingwell@aegic.org.au)

Collaborating organisations: ¹AEGIC; ²UWA

In 2017, research focuses on grain supply chain analysis, with grain supply chains in Australia, Argentina and the USA examined. Major industry reports outlining that research will be released in 2018.

Other research activity has involved reviewing changes in grain catchments in Australia and undertaking with international collaborators a comparative analysis of the funding of wheat breeding in Australia, Canada and France.

In 2017, Professor Ross Kingwell was awarded the Quality of Research Communication prize by the Australasian Agricultural and Resource Economics Society.

2: Professor Ross Kingwell was awarded the Quality of Research Communication prize by the Australasian Agricultural and Resource Economics Society in 2017.





Vertical coordination and food safety standards in Indonesian shrimp value chain

Project team: Dr Amin Mugera (leader; amin.mugera@uwa.edu.au), Ms Maharani Yulisti (PhD candidate), and Dr James Fogarty

Food safety standards (FSS) have received significant attention in the fisheries global market due to health concerns, free trade agreements and increasing aquaculture production. Tight vertical coordination is needed throughout the supply chain of seafood producing and exporting countries to meet food safety demands imposed by importing countries.

However, high transaction costs in organising and coordinating activities along the supply chains can result in difficulties in implementing FSS. To meet the stringent international food standards, several vertical coordination mechanisms, such as spot market transactions, contracts, or full vertical integration, can emerge. These can affect the ability of smallholder farmers from developing countries to benefit from participating in global value chains.

Different forms of vertical coordination can shape conditions for adopting and implementing food safety standards and participating in export markets. Therefore, understanding how the coordination of process food value chains affect the implementation of food safety standards is crucial for enabling the design of better institutional arrangements that will ensure improved smallholder welfare in developing countries.

This project has three main objectives. First is to investigate the emerging governance structure of the shrimp industry in Indonesia and understand how this structure influences the implementation of food safety standards. Second, the study analyses whether the adoption of food safety standards (the Indonesian General Agricultural Practices [IndoGAP]) in fish and shrimp production has economic benefits to smallholder producers. Economic benefit is measured by yield and revenue per hectare. Third, the study investigates key factors that shape the shrimp value chain. It analyses the key determinants of vertical coordination arrangements by producers; that is, whether producers operate in the spot markets, under contract arrangements, or produce for export market in a vertically integrated system.

PhD candidate Maharani Yulisti analysed data from survey and in-depth interviews with key stakeholders to address those three objectives. This project will be completed by early 2019.

This project is supported by the Australian Award Scholarships.

3: Fishing in shrimp ponds. Aceh, Indonesia. Photo: Mike Lusmore



Agricultural innovations for communities (AI-Com) in East Timor

Project team: Professor William Erskine¹ (leader; william.erskine@uwa.edu.au), Hackett Professor Kadambot Siddique¹, Professor Anu Rammohan¹, Dr Pyone Thu¹ and Dr Amin Mugera¹.

Collaborating organisations: ¹UWA; Ministry of Agriculture and Fisheries (MAF), National University of Timor-Lorosa'e (UNTL) and World Vision.

The aim of this project is to improve agricultural productivity and profitability in pilot communities in East Timor by addressing technical and social impediments to annual crop intensifications, and establishing fodder tree legumes and sandalwood, to sustain both income and land. The project is being implemented by a program management group including MAF, UNTL, World Vision and UWA, with inputs from major development and private industry partners. It builds on the successful collaborative project management approach used by Seeds of Life. The project aims to:

- 1 Understand community decision-making for natural resources management (NRM) and to pilot land use practice change
- 2 Understand and develop intensive irrigated cropping systems that can be applied to sustainably utilise limited spring-fed irrigation water in mid-altitude and groundwater on the south coast (of East Timor)
- 3 Understand and develop crop management packages to intensify annual rainfed cropping and increase the financial viability of maize, peanut, cassava and food legume producers
- 4 Design and evaluate methods and practices for communities to increase forage supply from tree legumes and sandalwood production to provide both short-term and long-term economic opportunities

An inception meeting of the AI-Com joint research project was held in Dili, Timor Leste, 26-28 April 2017. The launch was on 26 April 2017 followed by a 2.5 day planning session, including a field trip to one of the targeted locations in Maliana. The meeting was attended by representatives of all partners (ACIAR, UWA, MAF, UNTL and World Vision) and a wider representation of other actors in agriculture in Timor Leste. More than 125 people attended the launch.

Following the meeting the social-economic team of the project from UWA – Professor Anu Ramohan, Dr Pyone Thu, Dr Amin Mugera, together with Ms Detaviana Freitas of the Ministry of Agriculture and Fisheries – developed a baseline questionnaire in June 2017. The survey aims included establishing a social and economic baseline profile of each target community and understanding how communities make decisions over specific natural resources, current land use practices, legal, customary and social regulations over natural resources, and future land use aspirations.

In October 2017 Dr Pyone Thu (UWA) and Ms Detaviana Freitas trained four UNTL (National University of Timor-Lorosa'e) students and two MAF (Ministry of Agriculture and Fisheries) staff who were contracted as e-numerators for the household questionnaire. The training focused on the research process, ethics, use of e-questionnaires, introduction to open data kit (ODK) and how to use it to collect survey data. A baseline household survey was conducted in October in four communities in the municipality of Bobonaro. The field work was led by Dr Prone Thu.

This project is supported by an ACIAR grant.

4: The AI-Com team doing fieldwork in Maliana, East Timor. Photo: Amin Mugera.



Role of social protection in reducing poverty and vulnerability to poverty

Project team: Dr Amin Mugera¹ (leader; amin.mugera@uwa.edu.au), Dr Mohammed Azeem², and Professor Steven Schilizzi¹

Collaborating organisations: ¹UWA; ²The University of Agriculture Faisalabad, Pakistan, ³University of New England

Empirical studies in different developing countries have investigated the impact of social protection (SP) on alleviating poverty. However, few studies have analysed the role of social protection in reducing the vulnerability to poverty. With the world nations agreeing to end poverty and all its manifestations by 2030, as encapsulated in the first objective of the Sustainable Development Goals, governments and donor funding agencies in developing countries need to know whether providing short-term social protection reduces poverty and vulnerability to poverty.

This project investigated whether providing social protection to households reduces poverty and vulnerability to poverty in the Punjab province of Pakistan. The impact of social protection on households' current consumption expenditure was estimated from the Multiple Indicator Cluster Survey collected in 2011.

The survey involved about 90,000 households from rural and urban areas. The likelihood of a household moving in or out of poverty (vulnerability to poverty) in the near future was estimated using statistical methods.

The study then examined whether the main sources of vulnerability to poverty were stemming from household-specific factors or community-related shocks like flood. The results were used to test the effectiveness of SP in reducing households' idiosyncratic and covariate vulnerability. This was accomplished by using matching methods and simultaneous endogenous switching regression to control for potential selection bias and estimate average treatment effects.

The study found that SP has a positive impact in reducing household poverty and vulnerability to poverty.

The project is supported by UWA Pakistan Flood Reconstruction Scholarship and the Australian Award Scholarship.

5: Social protection in Pakistan has a role in reducing vulnerability to poverty. Photo: Jenny Downing.



Enhancing adoption of agricultural technologies requiring high initial investment among smallholders

Project team: Dr Amin Muger¹ (leader; amin.mugera@uwa.edu.au), Dr Yigezu Yigezu², Dr Tamer El-Shater², Dr Aden Aw-Hassan², Dr Colin Pigg², Dr Atef Haddad², Mr Yaseen Khalil^{1,2}, and Dr Stephen Loss³

Collaborating organisations: ¹UWA, ²International Center for Agricultural Research in the Dry Areas, ³Grain Research and Development Cooperation

The rate of adoption of improved agricultural technologies among smallholder producers in developing countries is often low and slow, thus frustrating the efforts for technology development and promotion. This is even more critical for agricultural technologies requiring high initial investment.

In 2005 the International Center for Agricultural Research in the Dry Areas (ICARDA) launched a project to introduce and promote zero tillage (ZT) to farmers in Iraq and Syria. The project adopted participatory methods to increase farmers' exposure to the new technology to encourage them to try it out and eventually adopt. Farmers were encouraged to carry out demonstration trials on their own farms by availing locally-made low cost ZT seeders to first-time users at no cost for up to two years. Technical assistance and extension services were also provided. After the two years, farmers were left to decide whether they wanted to adopt the technology using their own or rented ZT seeders. Farmers were also encouraged to adopt other conservation agriculture (CA) practices, such as early sowing, use of low seed rates and residue retention.

We investigated whether increasing farmers' awareness and exposure to zero tillage technology by making seeders available for use at no costs increased the rate of adoption. The project analysed data collected from a rural household survey of 820 smallholders producing wheat and barley in Syria. The results show that increasing exposure and awareness of the zero tillage technology through organised field days and demonstration trials, complemented with providing free access to costly zero tillage seeders for first-time users, increases the propensity, speed, and intensity of adoption. The intensity of adoption is also positively influenced by wheat acreage and farmers' access to credit.

The findings of this study highlight the importance of facilitating farmers' initial exposure and ease of trying out new agricultural technologies, especially those requiring high initial investment, at low or no cost to ensure fast and large-scale adoption.

This study also showed the importance of integrating research with development by allowing farmers to hold demonstration trials on their own farms as a pathway to promote uptake of new innovations and agricultural development. It also demonstrated the importance of providing risk-free environment to promote uptake on new technologies that require high initial investment

The project was funded by Australian Centre for International Agricultural Research (ACIAR).

6: Making seeders available for use at no costs provides a risk-free environment to increase the rate of adoption. Photo: Yaseen Khalil.

Sustainable agricultural intensification practices for food and environmental security

Project team: Dr Amin Mugeru¹, Assoc/Professor Atakelty Hailu¹, Wilckyster Nyarindo¹ (PhD candidate; wilkister.ogutu@research.uwa.edu.au), and Professor Gideon Obare²

Collaborating organisations: ¹UWA, ²Egerton University, Kenya

With a global population expected to double by 2050, producing food to ensure food security with minimum negative impact on the environment is one of the most pressing problems facing society today. Agricultural sustainable intensification (SI) has been gaining attention in policy discussions in international development as the most appropriate means to use land in order to increase food supplies while protecting biodiversity and ecosystem processes. It is seen as a means of achieving the twin goals of food security and environmental security, especially in sub-Saharan Africa, where population growth is high while food insecurity and environmental degradation are common. Sustainable intensification is defined as producing more units of output per units of all inputs and through new combinations of inputs, such as maize-legume intercropping, and related agricultural innovations. It also involves changing land use from low value crops or commodities to those that receive higher market prices. The goal of SI is improving physical input-output relations and increasing the overall efficiency of production. However, although several donor-funded projects have been implemented in sub-Saharan African countries to promote the adoption and use of sustainable agricultural intensification practices (SAIPs), there is insufficient empirical evidence on whether this is helping the smallholder farmers to increase output per unit of land, increase income, or reduce yield variability.

Economic evaluation of welfare effects of adoption of sustainable agricultural intensification practices among small maize-legume producers in Kenya

This research project aims to evaluate key determinants of adoption of different sustainable agricultural intensification practices (SAIPs) and market participation among smallholder maize-legume producers in Kenya, and their welfare effects as measured by the impact on crop yield, farm income, and food security status for households. The study used data from three-period repeated surveys conducted by the Adoption Pathway Project (APP) in Kenya. The SAIPs considered in the study include use of fertiliser, herbicide, pesticide, improved seed varieties, zero / minimised tillage, legume intercrop, legume rotation, animal manure, and soil and water conservation under maize legume farming systems.

Research objectives:

- To develop and estimate SAIPs package adoption choices and their effects on yield over time among smallholder farmers.
- To evaluate the intertemporal dimensions of smallholders productivity and production risk under adaptation to climate shocks.
- To investigate key determinants of farm households' participation in markets, choice of marketing channels and output prices received by farmers.
- To evaluate the effects on household food security of adopting SAIPs.

The research is expected to advance knowledge on the welfare effects of smallholder farmers adopting SAIPs and improve understanding how they choose marketing channel. It will help design suitable policies that can spur economic growth in the rural economy.

PhD candidate Wilckyster Nyarindo spent the first half of the year 2017 developing a research proposal to address the outlined objectives. She travelled to Kenya to organize and clean rural household survey data collected in 2011, 2013 and 2015 by the Adoption Pathway Project (APP) in Kenya.

The project is funded by Australian Centre for International Agricultural Research (ACIAR)

7: Rainfed maize production systems of Ethiopia. Photo: Ali Oumer.

Economic Evaluation of Territorial Use Rights for Fisheries with common property problems

Project team: Ms Nguyen Thi Quynh Chi (Phd Candidate; thi.q.nguyen@research.uwa.edu.au), A/Professor Steven Schilizzi, Assoc Professor Atakelty Hailu, and Dr Sayed Iftekhhar

Territorial Use Rights for Fisheries (TURFs), a form of area-based management systems, has recently emerged as the most promising tool for helping small-scale fisheries tackle the problem of over-exploitation. This project sets out to improve our understanding of fisher behaviour under institutional settings associated with co-managed TURFs and demonstrate how this can help build robust institutions that are favourable to sustainable fisheries.

Sustainable fisheries management largely depends on how effectively fishing regulations are enforced, which often relies on active monitoring by fishers. If fishers perceive that monitoring schemes do not fulfil their needs, they will resist participating in monitoring. However, fisheries managers worldwide have been making blanket assumptions about the way fishers respond to monitoring schemes. Although this has been proven to be a common mistake, the literature has remained almost silent about heterogeneity of fisher preferences for monitoring schemes, and how it affects their participation.

This project helps close this knowledge gap by carrying out a choice experiment with artisanal fishers in Vietnam to elicit preferences and value key design elements of monitoring schemes. This is the first study to investigate fishers' preference heterogeneity using an advanced technique the Scale-Adjusted Latent Class model that accounts for variance in both preferences and scale. We identified five distinct preference classes. Remarkably for a poor community, monetary compensation was found not to be the prime driver of fishers' choices. A one-size-fits-all monitoring scheme is ill-suited to all fishers. The design of flexible schemes can be an effective way to enhance the likelihood of fisher participation and the effectiveness of regulation enforcement.

PhD candidate Nguyen Chi conducted field work in Vietnam and analysed survey data from fishers to address the research questions.

This project is funded by UWA and the Australia Awards Scholarship.

8: A fishing village on the coast of Vietnam. Photo: JvL



How would mixed farmers respond to agricultural greenhouse gas abatement incentives?

Project team: Mr Kai Tang (PhD candidate; kai.tang@research.uwa.edu.au), Dr Atakelty Hailu, Dr Marit Kragt and Dr Chunbo Ma

As countries become more interested in finding ways to encourage farmers to adopt practices that can reduce greenhouse gas (GHG) emissions, researchers have sought to estimate how high incentives need to be for farmers to modify their practices. Estimates vary and are rarely based on a detailed analysis of the land use options available to farmers.

This project employed an advanced whole-farm bio-economic model with GHG extensions to assess the changes in land-use patterns, farm practices and on-farm GHG emissions under varying levels of agricultural abatement incentives in the form of a carbon tax for a broadacre farming system in WA's Great Southern Region. The project results have been published in an article in *Agricultural Systems*. The results show that broadacre agriculture offers relatively low-cost options for reducing GHG emissions through changing land-use patterns and farm management practices.

Since livestock are the dominant emissions source, the use of incentives for carbon mitigation would mean that the optimised enterprises mix would shift further towards cropping. Farmers would also tend to include less canola-based rotations and more field-pea-based rotations in their optimal enterprise mix. The estimates show that broadacre farmers in WA may abate their on-farm emissions to help meet the national goal, with marginal abatement costs not higher than \$20/ton CO₂-equivalent in 2015 Australian dollars.

The project is funded by UWA and the International Postgraduate Research Scholarships (IPRS)

Executive Education Programs

Project Team: W/Professor Tim Mazzarol (leader; tim.mazzarol@uwa.edu.au), Dr Elena Mamouni Limnios, W/Professor Geoff Soutar

The Co-operative Enterprise Research Unit (CERU) ran the following Executive Education Programs for the directors and senior managers of co-operative and mutual enterprises:

- Three day Cooperative and Mutual Enterprises (CME) Strategic Development Program for iCoops Malaysia held in Perth 29 November to 1 December 2017 for several of the leading Malaysia co-operatives. This program was undertaken in conjunction with the Australian Institute of Management (AIM) WA via the AIM WA – UWA Business School Executive Education Programs joint venture.
- Special Interest Group (SIG) program for co-operatives and mutual enterprises held within the Australian and New Zealand Academy of Management (ANZAM) annual conference in Melbourne 5-8 December. This included collaborating with the Business Council of Co-operatives and Mutuals BCCM to put on a special event and panel session on the CME as a competitive business model on Wednesday 6 December at the Kelvin Club in Melbourne CBD. This event was well attended with over 100 people present. The event enabled the presentation of some of the research undertaken by CERU to be show cased.

Integrating Artificial Intelligence in Farm Performance Analytics

Project Team: Dr Amin Mugera¹ (leader; amin.mugera@uwa.edu.au)

Can Artificial Intelligence (AI) be used to predict the performance of agribusiness enterprises? Artificial intelligence is emerging as a powerful tool that can be used to improve agricultural productivity. It is increasingly being used in agriculture to improve agricultural productivity and for soil and crop monitoring. For example, farmers are using sensors for soil sampling. However, the application of AI to farm performance analytics is still limited. There is a need for building predictive models that can be used to predict farm performance as measured by productivity and profitability. This could help in policy design to address challenges that require information about potential productivity, efficiency, and profitability of agribusiness enterprises.

Dr Amin Mugera took a six months sabbatical leave to explore and investigate how AI can be used to build predictive models for farm performance. Using a large farm level dataset spanning over ten years, he investigated how deep learning algorithms can be used in conjunction with mathematical programming models, like data envelopment analysis, to develop predictive models for farm performance relative to that of similar farms in the same industry.

Specifically, he looked at building models to predict farm technical efficiency and productivity. He also explored how deep learning algorithms can be used to cluster farms into different categories for the purpose of identifying attributes of farms that enable them achieve above industry average performance over time (i.e. sustained competitive advantage). This research project is ongoing.

2nd Workshop on Facilitating Agribusiness Development in Brunei Darussalam

Project Team: Dr Amin Mugera¹ (leader; amin.mugera@uwa.edu.au), Adj/Professor Peter Batt¹, Adj/Professor Nazrul Islam¹

Collaborating organisations: ¹UWA; Department of Agriculture and Agrifood, Brunei

To facilitate exports of fresh and processed agrifood products from Brunei Darussalam, an intensive four-day workshop (30 January to 2 February 2017) was conducted at the Horticulture Business Centre, Rimba, with government and private enterprises.

The workshop aimed to identify key institutional impediments to agribusiness development in Brunei Darussalam. This was a follow-up workshop after the successful first workshop conducted in Bandar Seri Begawan in April 2016. It was developed in consultation with the Brunei Department of Agriculture and Agrifood (DoAA) to build on the findings of an exploratory workshop conducted with senior executives from DoAA after the previous training course.

A total of 50 participants from DoAA and the private sector were trained. The interactive and intensive training was provided by Dr Amin Mugera, Professor Peter Batt and Dr Nazrul Islam from IOA. Participants were first introduced to the concept of value chains during the introductory workshop and asked to work in groups to provide a sketch of the value chains for selected agricultural products (fruit, vegetables, chicken and processed meat) in Brunei.

This exercise proved invaluable in getting them to start working together and thinking about the various actors involved in getting products to downstream customers, the activities that these actors undertook and the resources that they required to perform their roles. It was apparent that few were able to see the chain in its entirety, with most groups failing to recognise the importance of the upstream input supply sector, government and the service sector. Rather than this being a disadvantage, it established the need for and indeed reinforced the need for each of the modules which were to follow.

The day one training module established the need to understand what downstream buyers wanted and the roles that wholesalers and distributors played in getting products to institutional buyers (restaurants, food processors, manufacturers and retailers) and ultimately to consumers. Day two began with a vigorous discussion on alternative business models as a means of attracting investment and of linking products to markets. The range of options presented varied from the market coordination and relational coordination to vertically integrated production and marketing systems. Numerous examples were provided to illustrate the advantages and disadvantages of each alternative. In the afternoon session, participants discussed the need for agricultural cooperatives as a means for integrating smallholder farmers into high value institutional markets. Day three began with discussions to evaluate the performance of the value chains that participants had constructed on day one. In the afternoon session, participants returned to their groups to identify the key institutional constraints present in their selected value chains and to propose workable solutions to improve performance.

After this workshop, certificates were presented to participants in the presence of the Permanent Secretary of the Ministry of Primary Resources and Tourism, Dr Haji Abdul Manaf bin Haji Metussin. At the closing ceremony, the Australian High Commissioner Her Excellency, Ms Nicola Rosenblum, said the Australian Government, through the Australia-ASEAN Council, was pleased to have supported the workshop. Feedback was extremely positive and the workshop received wide media coverage in Brunei and Asian regions.

This project was supported by the Australian ASEAN Council.

9: Participants at the 2nd Workshop in Brunei. Photo: Rukiah Bair.



9

Factors Influencing the Member Value in Agricultural Co-operatives in Vietnam

Project team: Mr Pham Trung Tuan (PhD Candidate; 21419114@student.uwa.edu.au) Winthrop Professor Tim Mazzarol, Dr Elena Mamouni Limnios.

This project investigates the factors influencing the value that agricultural co-operatives provide to members, specifically small holder farmers, in Vietnam. In particular the influence of institutional factors, such as the role played by government and government agencies that regulate and support the co-operatives sector in that country, as well as the quality of the governance of these co-operatives.

A case study of high and low performing co-operatives were drawn from rice, vegetables and poultry sectors across both northern and southern Vietnam. In-depth interviews were undertaken with directors and managers from these co-operatives as well as officials from government regulatory agencies responsible for the co-operatives sector. The study is part of Mr Phan Trung Tuan's PhD candidature and is due to conclude in 2018.

This research is supported by AusAid.

Value Congruence between Australian small business member firms and their Co-operatives

Project team: Shahid Rahim Ghauri (PhD Candidate; shahid.ghauri@research.uwa.edu.au) Winthrop Professor Tim Mazzarol, Winthrop Professor Geoffrey Soutar

This project investigates the perception of value and the congruence of values that exist between co-operatives and their members where the members are small business owners. Theories of member loyalty and commitment to co-operative enterprises suggest that economic and social forces play a role. However, there is relatively little research available on the perception of value and the level of values congruence, between the co-operatives and their members where the members are small business operators (e.g. retail shop owners, farmers).

As part of Shahid Rahim Ghauri's PhD studies, in-depth interviews with members, managers and directors of co-operatives in Australia in the agriculture, fishing, building and motor trades sectors are being conducted. Data collection using an online member survey will be conducted in 2018.

Key Drivers of Engagement in the UFCC business model: What drives member, management and director responses to social and economic outcomes in Co-operative and Mutual Enterprises (CMEs)

Project team: Mr John Hassell (PhD Candidate; boyangs@treko.net.au) Winthrop Professor Tim Mazzarol, Dr Elena Mamouni Limnios

This project investigates the lifecycle of the United Farmers' Co-operative Company (UFCC) that operated from 1992 to 2008 supplying fertiliser to WA grain producers. As a single longitudinal case study, the UFCC co-operative offers a number of potentially valuable insights into the factors that influence success and failure in a co-operative.

The study forms part of Mr John Hassell's PhD research where he is examining the historical records of the company, conducting in-depth interviews with former directors, managers and members to triangulate their data against existing theories associated with the lifecycle of co-operatives and the factors that drive and shape success and failure.

7

Education and Outreach Activities



Strengthening communication links with industry, farmer groups and the broader regional and scientific communities is one of IOA's key strategies. A number of communication channels are used to ensure the University's research in agriculture and related areas is shared with its intended audience. IOA plays an active role in listening to growers, advisors and agribusiness professionals, to ensure two-way communication and that all ideas and perspectives are considered in the identification of key issues and opportunities.

IOA Postgraduate Showcase: Frontiers in Agriculture

The IOA Postgraduate Showcase: Frontiers in Agriculture is an annual event which brings together some of UWA's best postgraduate students to share their research in agriculture and related areas with an audience of farmers, academics, scientists and representatives from industry and government.

This year, IOA celebrated the eleventh consecutive event, with eight students from the Faculty of Science, Faculty of Health and Medical Sciences, and Faculty of Arts, Business, Law and Education presenting.

UWA's Vice Chancellor Professor Dawn Freshwater gave the opening address, and the two sessions were chaired by Professor Trevor Mori, Senior Research Fellow, UWA Medical School, and Professor Sarah Dunlop, Head of School of Biological Sciences.

The presentations can be viewed at ioa.uwa.edu.au/publications/showcase.

Ms Nicola Bondonno	Cardiovascular health benefits of apples and apple polyphenols
Mr Omar Al-Awad	Ammonium toxicity and resistance in canola genotypes
Ms Mary-Anne Lowe	Soil water repellence: limitations on water infiltration and its spatial distribution attributing to loss of agricultural productivity
Ms Lauren Blekkenhorst	Cardiovascular health benefits of vegetables and their components
Mr Md Shahin Uz Zaman	Water logging tolerance in field peas
Mr Robertson Khataza	Economic analysis of the integrated maize-legume production system in Malawi
Ms Karen Frick	Genomic research for the improvement of narrow-leaved lupin grain
Ms Haiyan Liu	The income and price sensitivity of diets globally

1: Postgraduate students shine at showcase.



IOA Industry Forum

Consolidation in agriculture: impacts to the farm, research and agribusiness

More than 200 people, including representatives from across the agriculture industry, academics and students, came together in July for the 11th Industry Forum, to deliberate the worldwide trend of consolidation. Specifically on the agenda was how consolidation in the agriculture sector impacts the farm, research and agribusiness.

UWA's Vice-Chancellor Professor Dawn Freshwater made the introductory remarks and welcomed Regional Development and Agriculture and Food Minister Alannah MacTiernan to officially open the forum. Minister MacTiernan congratulated UWA on being ranked first in Australia for agriculture science and 14th in the world in the Academic Ranking of World Universities 2017..

ACCC Commissioner Mr Mick Keogh delivered the keynote address and said there was an understandable impetus for firms to consolidate. He also said the digital revolution, in particular the rights over access to data and the purposes it can be used for, can limit the potential anti-competitive effects of market consolidation.

Planfarm's managing director Mr Greg Kirk said farming in WA was following the global trend of consolidation and that the demographics of WA's family dominated sector suggest consolidation is here to stay.

Focusing on the research sector, Dr John Manners, CSIRO director of agriculture and food said the efficiency and scale generated from consolidation will allow new efficiency and productivity technologies to thrive, but that this encourages uniformity not diversity.

Rabobank's head of Raboresearch food and agriculture Mr Tim Hunt agreed, saying big corporations had a tendency to concentrate on big markets, which creates opportunities for niche markets and start-ups.

The forum closed with a panel discussion, where Grain Industry of WA (GIWA) CEO Larissa Taylor, and InterGrain CEO Tress Walmsley joined the speakers on the panel, facilitated by Dr Graeme Robertson.

The Industry Forum was supported by CSBP Fertilisers through the CSBP and Farmers Ltd Golden Jubilee of Agriculture Science Fellowship. For the full program and access to presentations, see ioa.uwa.edu.au/publications/industry-forum

2: L-R: Kadambot Siddique, Larissa Taylor, Tim Hunt, Greg Kirk, Terry Enright, Tress Walmsley, Mick Keogh, John Manners and Graeme Robertson.





Dowerin Field Days

Technology was the focus of IOA's display at this year's Dowerin Field Days in August, where staff and students once again joined in the DPIRD exhibition.

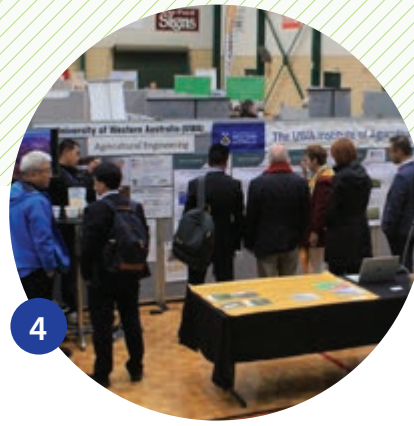
Co-leader of IOA's Engineering Innovations for Food Production research theme Dr Andrew Guzzomi from the School of Mechanical and Chemical Engineering attended the field days to interact with attendees about his research and UWA's plans to launch a Master of Agricultural Engineering.

Third-year PhD candidate Candy Taylor detailed her research to field day attendees and the Hon Alannah MacTiernan, Minister for Regional Development, Agriculture and Food.

UWA Honours Student Andrew Henson also took the opportunity to recruit farmers to participate in his study on understanding the willingness of farmers to pay for a range of grower group services.

This year, Schools Partnership Coordinator Sasha Peppinck, from UWA's Aspire program joined IOA's display. Sasha spoke to potential students from schools and agricultural colleges in the region about studying at UWA, the courses available and pathways to get there.

3: PhD candidate Ms Candy Taylor speaks with Hon Alannah MacTiernan about her research on narrow-leafed lupins



Techspo

The IOA team participated in Techspo, 12-14 September 2017, a technology expo held in Katanning. The event, which was organised by grower group Southern Dirt focussed on Dirt, Data and Droids.

Professor Lorenzo Faraone from the School of Electrical, Electronic and Computer Engineering and IOA presented his research on field-portable sensors for farming in the 21st century, Dr Joel Kelso from the School of Computer Science and Software Engineering detailed the Australis wildfire simulation system which will enable users to predict the spread of all large wildfires in Western Australia, and Dr Andrew Guzzomi from the School of Mechanical and Chemical Engineering and IOA discussed how global food production will become increasingly dependent on advances in engineering.

Also in attendance were Professor Graeme Martin from the UWA School of Agriculture and Environment and IOA, Future Farm 2050 Project Officer Debra Mullan and IOA Communications Officer Diana Boykett.

4: UWA's agricultural engineering strengths on display at Techspo in Katanning.



GRDC Grains Research Update, Perth

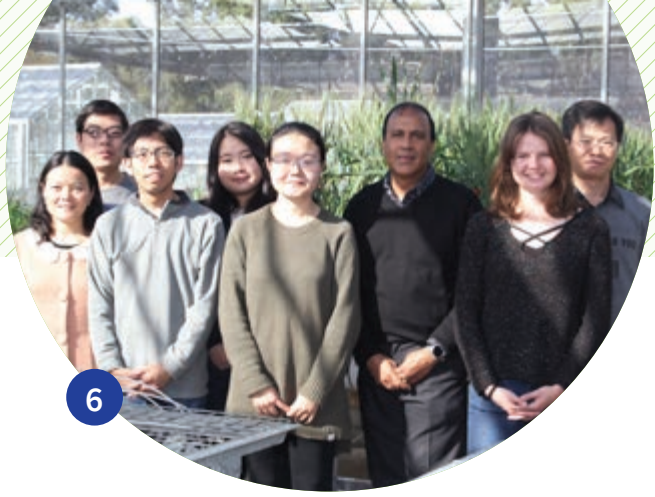
UWA was well represented at the 2017 Grains Research Update, Perth held at Crown Perth, Burswood on 27-28 February 2017. The two-day program showcased the latest research, technology, market development and management innovations to improve the productivity of the WA grains industry.

Five UWA students Ms Candy Taylor, Mr Nathan Craig, Mr Yaseen Khalil, Ms Ly Le and Mr Enoch Wong were awarded scholarships from the Australian Grains Innovation Capacity Building Project to attend the event, as part of their Careers in Grain initiative.

One of the scholarship recipients PhD Candidate Yaseen Khalil, gave an engaging presentation on his research into the effect of crop residue and rainfall on the availability of pre-emergent herbicides in the soil, which was very well received by the industry.

Other presenters from UWA were Professor Martin Barbetti, Dr Roberto Busi, Mr Nathan Craig and Dr Dusty Severtson.

5: PhD candidate Yaseen Khalil was one of five UWA students to receive the Careers in Grain scholarship.



Visitors to IOA

Over 70 visitors from 16 countries were welcomed to IOA in 2017. Visitors included scientists from partner organisations, industry stakeholders and government representatives.

Amongst the visitors was Dr Wenqing Zhao from Nanjing Agricultural University, China who spent 12 months as a Visiting Research Fellow at IOA from February 2017.

These interactions with staff and students are critical to knowledge sharing and to strengthening research links and collaborations both nationally and internationally.

For a full list of visitors to IOA during 2017, see ioa.uwa.edu.au/publications/newsletters

6: IOA hosted visitors from over 16 countries in 2017.

IOA News

IOA's broad range of activities is captured through its newsletter, *IOA News*. It is an important channel through which IOA promotes its research outcomes, collaborations, staff and student achievements and upcoming events to key stakeholders, alumni, the agriculture industry, funding bodies and UWA staff.

IOA News serves as a record of IOA's research activities and captures newly funded research projects, new staff and students, visitors to IOA and, importantly, a list of new peer-reviewed journals in agriculture and related areas.

Published three times per year – in May, August and December – *IOA News* is circulated widely in electronic format and hardcopy to over 6000 readers.

Online Presence

IOA's website, ioa.uwa.edu.au, provides an overview of the Institute's vision and mission, and is the first point of contact for people searching for information on activities in agriculture and related areas within the University.

Upcoming events are publicised on the IOA homepage along with a repository of the latest media statements distributed. Documents such as the IOA Strategic Plan, annual research reports and newsletters can also be found on the website.

Throughout 2017, IOA solidified its social media presence on Twitter @IOA_UWA. The number of followers doubled for the second year in a row to 620.

Public Lectures and Special Seminars

In 2017, IOA hosted six public lectures:

Date	Presenter	Organisation	Title
9 February 2017	Dr Christine Foyer	University of Leeds, UK	Setting the rhythm for cell division in plants
3 April 2017	Prof Snow Barlow	The University of Melbourne, Australia	Hector and Andrew Stewart Memorial Lecture The grand agricultural challenges of climate change
4 April 2017	Adj/Prof Brian Darlrymple	CSIRO	Applications of genomics in sheep and cattle: gastrointestinal tract, muscle and skin, and the evolution of ruminants
16 August 2017	Adj/Prof John Kirkegaard	CSIRO	Brian Carlin Memorial Lecture From dust bowls to food bowls: Australia's conservation farming revolution.
14 November 2017	Prof Henry Nguyen	University of Missouri, USA	Legume improvement for sustainable food production and human health
27 November 2017	Prof Vara Prasad	Kansas State University, USA	Concepts of sustainable intensification for improved food and nutritional security

7: IOA hosted six public lectures in 2017



Media Statements

IOA continued communicating its research outcomes to the general public through the media by distributing 25 media statements in agriculture and related areas throughout 2017. A substantial amount of media coverage was generated in local, rural, national and international print, broadcast and online media.

Date	Title
11 January 2017	UWA scientist wins prestigious senior TED Fellowship
23 January 2017	A novel avenue for breeding drought-tolerant wheat
8 February 2017	Teaching plants to be better spenders
24 February 2017	Tiny mutation makes plants less resistant to stressful conditions
6 March 2017	Researchers find the dark matter of the bread wheat genome
8 March 2017	New book tackles global dryland agriculture challenges
6 April 2017	Grain production and food security in China
11 April 2017	Study reveals plants 'listen' to find sources of water
12 April 2017	Pathogen uses light to facilitate invasion of wheat plant
20 April 2017	Wheat genome decoded to enhance food security
27 April 2017	UWA's international partnership to enhance global wheat yields
10 May 2017	Leading epigenome researcher earns international acclaim
23 May 2017	Scientists unlock potential of globally significant grain legume crop
9 June 2017	UWA partners Ausplow Farming Systems to optimise seeding performance
19 June 2017	Lentils can beat the heat
28 June 2017	Engineering solutions manage agricultural soil compaction
29 June 2017	Antimalarial drugs offer a smorgasbord of new herbicides
24 August 2017	Breakthrough in drought resistant barley
14 September 2017	Plant scientist first Australian to win top American award
18 September 2017	UWA Professor recognised for global leadership in agriculture research
3 October 2017	Compost and clay can ameliorate impact of water stress in agricultural soils
19 October 2017	New MOOC on best practice farming for 2050
2 November 2017	Plant biologist wins 2017 Young Tall Poppy Award
6 November 2017	UWA acknowledges Noongar Elders on Gnaala Karla Boodja
20 November 2017	Smart scholarship for agriculture students

Outreach and teaching activities at UWA Farm Ridgefield

In 2017, UWA Farm Ridgefield hosted approximately 300 visitors, comprised of students from UWA and other Australian universities, international university students and visiting academics (including from Freie Universität Berlin, University of Agriculture Faisalabad Pakistan, SupAgro Montpellier, France, and the Colorado School of Mines USA). In 2017, Ridgefield was also visited by regional and urban community members with an interest in the Future Farm 2050 Project (FF2050) and UWA Agriculture.

The key activity for outreach in 2017 at UWA Farm Ridgefield was hosting the Acknowledgement of Country ceremony in November. Noongar families joined staff and students from UWA in an Acknowledgement of Gnaala Karla Boodja ceremony. Noongar Elders Merv Abraham and Gary Bennell performed the Welcome to Country at the Old Farmhouse in front of a group of 30 people including their family members, the Pingelly community and UWA staff and students, including 15 international students.

Another key activity of the FF2050 outreach and teaching activities was the launch of the Massive Open Online Course (MOOC) “Discover Best Practice Farming for a Sustainable 2050”. The MOOC was launched on the online platform Coursera on 16 October 2017 and during the period 16 October - 31 December 2017, 840 students enrolled in the course. The course provides an overview of the four key enterprises of the FF2050 Project, sustainable agriculture in general and UWA. Individuals from all around the world can participate for free.

During 2017, approximately 80 UWA undergraduate students used Ridgefield for field work as part of the units “Pasture and Livestock Systems”, “Clean, Green and Ethical Animal Production”, and “Crops and Cropping Systems”. UWA Farm Ridgefield was added to the “Wheatbelt Science Hub Trail” – inspiring the discovery and excitement of science (wheatbeltscience.org.au/project/uwa-future-farm/) with a particular focus on secondary students in the wheatbelt region.

The FF2050 Project was also awarded the People’s Choice Award for Alumni Funds, which will be used to build a student learning hub at Ridgefield. This new learning hub will increase service learning across a range of disciplines at UWA. FF2050 Project won this award based on its ability to deliver fantastic outreach and teaching activities given the right tools. The student learning hub will be officially opened in 2018. The FF2050 Project was also awarded Community Partnership Funds to be used over three years to develop outreach in the Pingelly community. In 2017 the funds were used on extensive engagement with Pingelly Noongar elders to build strong relationships prior to undertaking any projects. The funds were also used to leverage additional funds to facilitate visiting scholar Dr Deirdre O’Connor to facilitate social farming in WA. Social farming offers people who avail a range of social/health services (including mental health, physical/intellectual disability, elder care, among others) or experience



social marginalisation, the opportunity to engage in the farming and related social activities of their communities.

FF2050 Project also used Community Partnership Funds to explore accommodation possibilities in Pingelly to allow students greater access to UWA Farm Ridgefield. Such accommodation would also benefit itinerant workers in Pingelly and users of the Pingelly Recreation and Cultural Centre (PRACC). Under the umbrella of the FF2050 Project and Community Partnerships, UWA Architecture Masters students visited Pingelly and developed a series of designs and ideas to benefit the town. These students will present their ideas to Pingelly Shire in early 2018.

Approximately 50 postgraduate students and Master of Science students visited UWA Farm Ridgefield to complement their studies or complete research. Ms Clemence Darley from SupAgro, Montpellier completed a four month internship, which is a requirement of her studies, at Ridgefield. Professor Graeme Martin and Emeritus Professor Lynette Abbott continued their regular engagement with Kelmscott Senior High School and specialist agricultural students to discuss the FF2050 Project and provide guided tours through UWA Crawley Campus.

A Farm Assistant internship was offered to Bachelor of Agriculture Science and Chemistry graduate, Mr Cameron Broun. The internship complemented Cameron’s formal studies at UWA and enabled him to gain practical experience applicable to industry and research. The FF2050 Project also provided work experience for UWA Agricultural Science student, Michael Young. Michael was involved in gaining practical agricultural experience and exposure to designing research trials and data collection.

A key workshop hosted at UWA Farm Ridgefield was the “WA Pasture and Livestock Update Brookton and Pingelly”. The workshop was attended by over 60 researchers, industry representatives and farmers. Topics included profitability of livestock within a mixed farming system; pasture varieties for here, there, but not everywhere; and chaff carts and crop grazing – do they stack up? An inspection of perennial pastures, shrubs and trees was part of the workshop.

Six journal papers from research based at UWA Farm Ridgefield were published in 2017. Journal articles covered research on soil compaction, invertebrate communities in the tree diversity project at Ridgefield, and sheep reproduction and temperament. In addition to journal papers, the FF2050 project was featured in 28 media stories, an important means of translating research to farmers, researchers and community members.

Awards and industry recognition for staff in 2017

Name	Award
Ms Myrtille Lacoste	Royal Society Commonwealth Science Conference 2017 travel award
Hackett Prof Kadambot Siddique	Award for excellence in international pulse research & development from the Minister for Agriculture Government of India
A/Prof Ross Kingwell	AARES Quality of Research Communication Prize
Mr Brenton Leske	Postgraduate Research Scholarship from Department of Primary Industries and Regional Development
Dr Marit Kragt	Research Fellowship from the Australian Research Council Centre of Excellence for Environmental Decisions (CEED) under the 2017 Visiting Fellowships program
Mr Simon Jankowski	Agribusiness Connect Masters Research Project Scholarship
Mr Andrew Hansen	Agribusiness Connect Honours Research Project Scholarship
Dr Yinglong Chen	Australian Academy of Science Travel Award to attend Science at the Shine Dome and EMCR Program, Canberra, 23–25 May 2017
Dr Yinglong Chen and Dr Jiayin Pang	WUN Symposium cum Research Summit Travel Award to present at WUM Grain Legume Conference, Hong Kong, 6–17 June, 2017
Dr Hari D Upadhyaya	Fellow of National Academy of Agricultural Sciences (NAAS), India 2017
Dr Hari D Upadhyaya	Fellow of Uttar Pradesh Academy of Agricultural Sciences (UPAAS) 2016 for his outstanding contribution in the field of Natural Resource Management (Biodiversity)
Prof Rajeev Varshney	Elected Fellow of German Academy of Sciences Leopoldina, Germany
Prof Rajeev Varshney	Elected Fellow of The World Academy of Sciences
Prof Rajeev Varshney	Doreen Margaret Mashler Award (the most prestigious award of ICRISAT) by ICRISAT Governing Board
Prof Rajeev Varshney	IPGI Award-2017 for leadership & contribution to peanut research by the International Peanut Genome Initiative
Prof Stephen Powles	American Chemical Society International Award for Research in Agrochemicals
Hackett Prof Kadambot Siddique	Global Research Leadership in Agriculture Award, Indian Council of Food and Agriculture, India
Prof Harvey Millar	WA Scientist of the Year 2017
Prof Rajeev Varshney	Elected Fellow, American Association for Advancement of Sciences
Ms Candy Taylor	Farrer Memorial Travelling Scholarship, NSW Department of Primary Industries
Prof Tim Colmer	Australian Society of Plant Scientists JG Wood Lecture at ComBio2017
Mr Daniel Kidd	Calenup Postgraduate Research Scholarship
E/Prof Lyn Abbott	Soil Science Fellowship
Prof Wallace Cowling	Member of the Program Committee, IRC 2019 Berlin, Germany
Dr Monika Murcha	Tall Poppy Award

Research Projects and Research Training

New Research Projects Awarded in 2017

Title	Funding Period	Funding Body	Supervisors
Increasing wheat yield by genomic sequencing and germplasm exchange	2017-2021	Ministry of Industry, Innovation and Science (Global Innovation Linkages)	Professors Guijun Yan, Jacqueline Batley and Dave Edwards
Integrated economic assessment and business case development for Water Sensitive Cities	2016-19	CRC for Water Sensitive Cities	Mr MD Sayed Iftekhhar, Professor David Pannell
Serpentine Managed Aquifer Recharge	2017	Greenacres Turf Group	Miss Sarah Bourke
AW Howard Memorial Trust Research Fellowship: Gustavo Striker visit to UWA for research on submergence tolerance of messina	2017	AW Howard Memorial Trust	Dr Gustavo Striker, Professor Tim Colmer
Frost tolerance in wheat: Grains Research Scholarship for field-based phenotyping tools in pre-breeding	2017-2020	GRDC Grains Industry PhD Research Scholarship	Professor Tim Colmer, Dr Ben Biddulph
Phosphorus-efficient Australian plants: applications for crop improvement	2017-2020	ARC Future Fellowship	Dr Ranathunge Ranathunge
Incorporating salt-tolerant wheat pulses into smallholder farming systems in southern Bangladesh	2016-2020	Australian Centre for International Agricultural Research (ACIAR)	Professor William Erskine, Professor Tim Colmer
Development of novel transcriptional regulators and synthetic logic gates for sophisticated control of plant activity and production	2017-2019	CSIRO Synthetic Biology Future Science Fellowships	Dr Brendan Kidd, Professor Ryan Lister, Professor Karam Singh, Professor Kemal Kazan
Using citizen scientists to test the effectiveness of biofertilizers	2017-2018	Department of Industry Innovation and Science Citizen Science Grants	Dr Barbara Cook
MicroBlitz: Super-sized citizen science for soil microbiomes	2017-2018	Department of Industry Innovation and Science Citizen Science Grants	Professor Andrew Whiteley
Infrastructure Grants 2017 – Crop and Weed Agronomy Laboratory	2017	Grains Research and Development Corporation (GRDC)	Professor Stephen Powles, Dr Kenneth Flower, Mr Michael Ashworth
Evaluation and development of castor bean as a commercial crop in Australia	2017-2021	Virtue Australia Foundation	Professor Kadambot Siddique, Dr Yinglong Chen
Markers, markets and validated nutritional qualities of Australian apples	2016-2018	WA Agricultural Produce Commission	Dr Michael Considine
Stress-resilient Phaseolus bean crops: addressing interactions of root rots with variable water availability under current and future climate scenarios	2017	ACIAR	Prof Martin Barbetti, Dr Joop van Leur
Policy Analysis of food safety and trade in Vietnam	2017-20	ACIAR	Dr Elizabeth Petersen, Dr David Vanzetti, Associate Professor Steven Schilizzi, Associate Professor Michael Burton, Professor David Pannell

Title	Funding Period	Funding Body	Supervisors
Food security and the governance of local knowledge in India and Indonesia	2017-18	University of Newcastle ex ARC Discovery Project	Professor Christoph Antons, Winthrop Professor Michael Blakeney, Professor Kadambot Siddique, Professor Dr Philippe Cullet, Associate Professor Yunita Winarto, Dr Gregory Acciaioli, Dr Jagjit Plahe
Plant-soil interactions through space and time: forecasts and ecological relevance	2018	UWA Research Collaboration Awards	Mr Michael Renton, Emeritus Professor Johannes Lambers, Associate Professor Etienne Laliberte, Dr Benjamin Turner, Dr Francois Teste
Development of novel transcriptional regulators and synthetic logic gates for sophisticated control of plant activity and production	2017	UWA Fellowship Support Scheme	Dr Brendan Kidd
Microbe mediated alternative Nitrogen nutrition in Australian seagrasses	2018	UWA Research Collaboration awards	Philipp Bayer, Matthew Fraser, Agnieszka Golicz, Jeremy Bougoure, Ursula Steinfert, J. Chris Pires
Structure-based investigations into new modes of action for herbicides	2018-20	ARC Discovery Early Career Researcher Awards	Dr Joel Haywood
Using improved markets to reduce over-extraction of groundwater	2018-20	ARC Discovery Early Career Researcher Awards	Mr MD Sayed Iftekhhar
Defining factors in the control of protein turnover in plants	2018-20	ARC Discovery Projects	Prof Harvey Millar
Innovative seed technologies for restoration in a biodiversity hotspot'	2018-2022	ARC Linkage Projects	Professor Richard Hobbs, Dr Todd Erickson, Dr Jason Stevens, Associate Professor Matthew Madsen, Dr Michael Forster, Mr Vernon, Mr Anthony Pekin, Mr Alan Savage
Climate-smart landscapes for promoting sustainability of Pacific Island agricultural systems - Phase 2	2018-21	Australian Centre For International Agricultural Research ACIAR	Dr Eloise Biggs, Mr Jan Helsen, Dr Eleanor Bruce, Dr Bryan Boruff, Dr Nathan Wales, Dr Viliami Manu, Professor John Connell, Ms Pyone Thu

New PhD research students

Twenty-three students commenced their postdoctoral studies in agriculture and related areas at UWA in 2017.

Name	Topic	School	Supervisor(s)	Funding Body
Mr Muhammad Shoaib Khan	How do essential oil compounds reduce methanogenesis	UWA School of Agriculture and Environment and IOA	Prof Philip Vercoe, Prof Graeme Martin	UAF-UWA scholarship
Mr Muhammad Azam Khan	Understanding and mapping of genes responsible for resistance against the fungal pathogen <i>Sclerotinia sclerotiorum</i> in canola (<i>Brassica napus</i>).	UWA School of Agriculture and Environment and IOA	Prof Martin Barbetti, Prof Wallace Cowling, Dr Mingpei You, Prof Jacqui Batley	UAF-UWA scholarship
Ms Tamsal Murtza	Understanding the pathogen and environmental drivers of white leaf spot (<i>Pseudocercospora capsellae</i>) epidemics and their impacts on canola	UWA School of Agriculture and Environment and IOA	Prof Martin Barbetti, Dr Mingpei You	UAF-UWA scholarship
Mr Waseem Abbas	Using respiration physiology to improve control of stored grain pests	School of Biological Sciences and IOA	Assoc/Prof. Theo Evans, Prof Philip Withers	UAF-UWA scholarship
Mr Muhammad Rafay Muzamil	The politics of climate change adaptation in the context of conflict: Implications for rural livelihoods in Khyber-Pakhtunkhwa province of Pakistan	UWA School of Agriculture and Environment and IOA	Prof Petra Tschakert, Dr Bryan Boruff	UAF-UWA scholarship
Mr Umair Hassan Khan	Transcriptome profiling of the rumen epithelium of sheep	UWA School of Agriculture and Environment and IOA	Prof Philip Vercoe, Prof Graeme Martin	UAF-UWA Scholarship
Mr Shamshad Ul Hassan	Molecular and cellular components of immune system in ruminants	UWA School of Agriculture and Environment and IOA	Prof Philip Vercoe, Prof Graeme Martin	UAF-UWA Scholarship
Mr Brenton Leske	Frost tolerance in wheat: field-based phenotyping tools in pre-breeding	UWA School of Agriculture and Environment and IOA	Prof Tim Colmer, Dr Ben Biddulph	GRDC Top-up Scholarship and Postgraduate Research Scholarship from the Department of Agriculture and Food Western Australia
Mr Daniel Kidd	Environmental factors limiting production and persistence of <i>Ornithopus</i> species	UWA School of Agriculture and Environment and IOA	Dr Megan Ryan, Prof Tim Colmer, Dr Richard Simpson (CSIRO)	Rural Research and Development for Profit via Meat and Livestock Australia
Ms Clementine Merce	Pangenome assembly and diversity analysis	School of Biological Sciences and IOA	Prof Dave Edwards, Prof Jacqui Batley, Dr Kenneth Chan	ARC
Ms Wilckyster Nyateko	Sustainability of Agricultural intensification practices among Maize-legume smallholders in Kenya	UWA School of Agriculture and Environment and IOA	Dr Amin Mugera, Dr Atekalty Hailu	Australia Awards

Name	Topic	School	Supervisor(s)	Funding Body
Mr Duong Nguyen	Genetic analysis of salt tolerance in chickpea	UWA School of Agriculture and Environment and IOA	Prof Tim Colmer, Dr Lukasz Kotula, Dr Tim Sutton (SARDI)	UWA RTP
Mr Lu Lu	Genomics of wheat yield	UWA School of Agriculture and Environment and IOA	Prof Guijun Yan, Dr Helen Liu	UWA RTP
Mr Guannan Liu	Genomic markers for lupin production	UWA School of Agriculture and Environment and IOA	Prof Guijun Yan, Dr Helen Liu	Full fee paying
Ms Thi Hue Vuong	Food Safety in Vietnam: Perceptions, behaviour, economics and policy	UWA School of Agriculture and Environment and IOA	Prof David Pannell, Assoc/Prof Steven Schilizzi, Dr Liz Peterson	Vietnam International Education Development scholarship
Mr Edi Wiraguna Dalimin	Combined salinity and waterlogging tolerance in grasspea	UWA School of Agriculture and Environment and IOA	Prof William Erskine, Prof Tim Colmer, Dr Imran Malik	Indonesian Educational Fund
Mr Buddhi Chaudhary	Role of Indigenous Knowledge in Innovation Systems: The Case of Tharu Indigenous Nationality in Nepal	School of Social Sciences, UWA School of Agriculture and Environment and IOA	Dr Gregory Acciaioli, Prof William Erskine	UWA RTP
Ms Maria Purnamasari	Camelina sativa – a source of phytoalexin-based resistance to important canola fungal diseases	UWA School of Agriculture and Environment and IOA	Prof William Erskine, Dr Janine Croser, Dr Parwinder Kaur, Prof Martin Barbetti	Indonesian Educational Fund
Mr Anqiang Tang	Identifying the molecular mechanisms of yield improvement in Western Australian wheat varieties	School of Molecular Sciences and IOA	Dr Nicolas Taylor, Dr Shaobai Huang, Prof Harvey Millar	UWA RTP
Mr Aygul Abzalov	Identifying the molecular responses of membrane lipids to heat and frost of temperature tolerant and sensitive Australian wheat varieties	School of Molecular Sciences and IOA	Dr Nicolas Taylor, Dr Monika Murcha	UWA RTP
Mr Yimin Wang	Identifying the molecular responses to predicted 2050 climate of Western Australian wheat varieties	School of Molecular Sciences and IOA	Dr Nicolas Taylor, Dr Monika Murcha	Full fee paying
Mr Atbin Mohabbati	Addressing to the missing data of OzFlux network using 'panel-data' method	UWA School of Agriculture and Environment and IOA	Prof Jason Beringer, Dr Matthias Leopold	UWA RTP
Mr Luoyang Ding	Effect of temperament genotype on sheep production	UWA School of Agriculture and Environment and IOA	Dr Dominique Blache, Prof Shane Maloney, Dr Jennifer Rodger	China Scholarship Council and SIRF

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The Theme Leaders co-ordinate research, development and related activities in their respective areas. It is chaired by IOA Associate Directors Professor Phillip Vercoe and Professor Wallace Cowling.

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The IAB provides the Institute with industry interaction, advice and feedback. IAB members represent a cross-section of agricultural industries and natural-resource-management areas.



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2017 Publication List

Peer Reviewed Journals

Abagna D and Muger A (2017). Food Poverty and Vulnerability to Food Poverty in Ghana: An Empirical Analysis. *Journal of African Development*

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Acronyms

ACIAR	Australian Centre for International Agricultural Research	IOA	The UWA Institute of Agriculture
ACMEI	Australian Co-operative and Mutual Enterprise Index	IoT	Internet of Things
AEGIC	Australian Export Grains Innovation Centre	INRA	French National Institute for Agricultural Research
AI	Artificial Intelligence	IPRS	International Postgraduate Research Scholarships
AI-Com	Agricultural innovations for communities	IRRI	International Rice Research Institute
AIM	Australian Institute of Management	KASP	Kompetitive Allele Specific PCR
ANABP	Australian National Apple Breeding Program	LED	Light-emitting diode
AOF	Australian Oilseed Federation	LHS	Left hand side
APP	Adoption Pathway Project	LPDP	Indonesia Endowment Fund for Education
ARC	Australian Research Council	MAF	Ministry of Agriculture and Fisheries, East Timor
ASEAN	Association of South East Asian Nations	MLA	Meat and Livestock Australia
aSSD	Accelerated Single Seed Descent	MOOC	Massive Open Online Course
AWI	Australian Wool Innovation	MTA	Marker-trait association
BARI	Bangladesh Agriculture Research Institute	NAAS	National Academy of Agricultural Sciences, India
BCCM	Business Council of Co-operatives and Mutuals	NAM	Nested association marker
BLUP	Best linear unbiased prediction	NILs	Near isogenic lines
CA	Conservation Agriculture	NIRS	Near Infrared Spectroscopy
CAS	Chinese Academy of Sciences	NME	National Mutual Economy
CAAS	Chinese Academy of Agricultural Sciences	NPZ	Norddeutsche Pflanzenzucht
CBH	Co-operative Bulk Handling (company)	NSW	New South Wales
CCU	Co-operative Capital Units	NSW-DPI	New South Wales Department of Primary Industries
CEED	Centre of Excellence for Environmental Decisions	OCS	Optimal Contribution Selection
CERU	Co-operative Enterprise Research Unit	OTM	Oral trans-mucosal
CIMMYT	International Wheat and Maize Improvement Center	P	Phosphorus
CME	Co-operative and Mutual Enterprise	PBA	Pulse Breeding Australia
CSIRO	Commonwealth Scientific & Industrial Research Organisation	PCR	Polymerase chain reaction
CONICYT	National Commission for Scientific and Technological Research, Chile	PHS	Pre-harvest Sprouting
CRC	Cooperative Research Centre	PNG	Papua New Guinea
CRCNPB	Cooperative Research Centre for National Plant Biosecurity	PRACC	Pingelly Recreation and Cultural Centre
CRCPB	Cooperative Research Centre for Plant Biosecurity	PRSV-W	Papaya ringspot virus biotype W
CW	Constructed Wetland	QTL	Quantitative trait locus
DEDJTR	Department of Economic Development, Jobs, Transport and Resources, Victoria	RHS	Right hand side
DoAA	Department of Agriculture and Agrifood, Brunei	RIL	Recombinant inbred lines
DPIRD	Department of Primary Industries and Regional Development, Western Australia	RIRDC	Rural Industries Research and Development Corporation
DNA	Deoxyribonucleic Acid	RNA	Ribonucleic Acid
DTS	Distributed temperature sensing	RTP	Research Training Program scholarship
EIAR	Ethiopian Institute of Agricultural Research	SA	South Australia
EO	Essential oils	SAIP	Sustainable agricultural intensification practices
EU	European Union	SARDI	South Australian Research and Development Institute
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database	SCFAs	Short-chain fatty acids
FF2050	Future Farm 2050 Project, UWA Farm Ridgefield	SI	Sustainable intensification
FSS	Food Safety Standards	SIRF	Scholarship for International and Research Fees
FTA	Flinders Technology Associates	TURF	Territorial Use Rights for Fisheries
GBS	Genotyping by sequencing	UAF	University of Agriculture, Faisalabad, Pakistan
GHG	Greenhouse Gas	UAV	Unmanned aerial vehicle
GIWA	Grains Industry Association of WA	UPA	University Postgraduate Award
GRDC	Grains Research and Development Corporation	UQ	University of Queensland
GWAS	Genome-wide association study	UNTL	National University of Timor-Lorosa'e, East Timor
ICARDA	International Centre for Agricultural Research in the Dry Areas	UWA	The University of Western Australia
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics	VIC	Victoria
		VFCW	Vertical Flow Constructed Wetlands
		WA	Western Australia
		WANTFA	Western Australian No-Tillage Farmers Association
		WUN	Worldwide Universities Network
		ZT	Zero tillage
		ZYMV	Zucchini Yellow Mosaic Virus



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