THE UNIVERSITY OF WESTERN AUSTRALIA | Institute of Agriculture

Annual Research Report

2024

Sustaining productive agriculture for a growing world

Vision

Our vision is to empower communities and individuals in Australia and the Indian Ocean Rim to improve their food, nutritional and health security, enhance local and regional prosperity and exercise responsible environmental stewardship.

Mission

As an international leader in dryland agricultural systems, we develop and communicate innovative evidence-based solutions for ethical food production, environmental sustainability and agribusiness advancement in state, national and international settings that enrich peoples' lives.

Strategies

Integration

Bringing together UWA's agricultural research and communication activities; integrating complementary activities across disciplines and organisational units and providing a focus for leading-edge research and innovation.

Communication

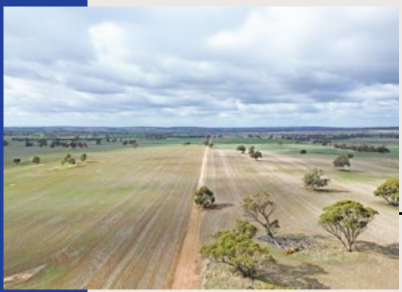
Strengthening links with regional industries, farmer groups and the broader regional, national and international scientific communities, in line with our Communications Plan.

Connecting

Fostering national and international linkages and alliances that bring new knowledge and expertise to WA and allow our institution to share its knowledge with the world.

Resourcing

Increasing the pool of resources available for investment in critical R&I in WA and relevant to national and international issues.



Aerial view of UWA Farm Ridgefield.
Credit: Ana Mendigutxia Balil

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The UWA Institute of Agriculture Annual Research Report 2024

Director’s overview

On behalf of The University of Western Australia (UWA), I am pleased to present the Annual Research Report 2024 of The UWA Institute of Agriculture (IOA).

This year’s report highlights the remarkable achievements of our researchers, including the publications of over 340 journal articles, books, and book chapters. We welcomed a new cohort of 17 PhD candidates and celebrated the recognition of several academics on the prestigious Highly Cited Researchers list, alongside numerous national and international accolades.

Our researchers’ dedication, rigour, and excellence contributed to a significant milestone: UWA was ranked 1st in Australia and 9th globally in Agricultural Sciences in the 2024 Academic Ranking of World Universities. This success reflects the strategic leadership of our six Research Themes: Sustainable Cropping Systems, Sustainable Animal Production Systems, Water for Food Production, Food Quality and Human Health, Engineering for Agriculture, and Agribusiness Ecosystems.

In 2024, IOA continued to strengthen engagement and enhance the visibility of our research. We were honoured to host Dr Ismahane Elouafi, Executive Managing Director of CGIAR for a three-day visit that included site tours, UWA Farm Ridgefield and the 30th Hector and Andrew Stewart Memorial Lecture. More than 250 visitors attended the Shenton Park Field Station Open Day, which showcased new pasture legumes and cross-disciplinary innovations. At UWA Farm Ridgefield, we welcomed the Governor of Western Australia, His Excellency the Honourable Christopher Dawson AC APM, and Mrs Darrilyn Dawson —affirming our commitment to innovation and community partnership. We also celebrated the 50-year contribution of Emerita Professor Lyn Abbott to soil science and STEM equity, highlighted by a dedicated symposium and the awarding of the UWA Chancellor’s Medal.

Sadly, 2024 also marked the passing of Emeritus Professor Alan Robson, former UWA Vice-Chancellor and long-time supporter of the IOA. A respected scientist and leader, he is remembered with deep appreciation for his lasting impact on UWA and Australian agriculture.

In 2024, we enhanced our engagement with a wide range of stakeholders—including industry partners, farmer groups, research collaborators, funding agencies, alumni, and the broader community.

Our strong portfolio of externally funded research continued, with active participation in major initiatives such as the Cooperative Research Centre for Solving Antimicrobial Resistance in Agribusiness, Food and Environments (CRC SAAFE) and the CRC for Net Zero Emissions in Agriculture. Throughout the year, the IOA released three newsletters, issued 27 media statements, and hosted 20 major events, collectively reaching more than 900 stakeholders from government, academia, industry, and the public.

I extend my heartfelt thanks to IOA staff, researchers, associates, students, Board members, Research Theme leaders, and our national and international collaborators and funding partners. The milestones we have reached reflect a shared pursuit of excellence, and I am deeply grateful for the professionalism, dedication, and spirit of collaboration that underpin our work.

Professor Kadambot Siddique AM CitWA
FTSE, FAIA, FNAAS, FAAS, FPAS
Hackett Professor of Agriculture Chair and Director

The UWA Institute of Agriculture
The University of Western Australia

IAB Chair and DVCR messages

As we reflect on 2024, the Industry Advisory Board (IAB) has proven once again to be a cornerstone in the Institute of Agriculture's (IOA) efforts to build a resilient and sustainable future for agriculture in Western Australia and beyond.

The Board, composed of passionate and forward-thinking farmers alongside influential leaders from the agricultural sector, has provided indispensable counsel and strategic direction. Their expertise has not only strengthened the IOA's relationship with the industry but has also positioned the Institute at the forefront of addressing global challenges in agriculture. Through their continued support, the IAB has played a crucial role in ensuring that the IOA remains agile, relevant, and impactful in its mission to support rural and regional communities and contribute to the advancement of sustainable agricultural practices worldwide.

The 18th annual Industry Forum, held in July 2024, was a standout event in our calendar, drawing an audience of over 270 attendees. This year, we tackled the urgent and often controversial question: *Can agriculture reach Net Zero?* The discussion brought together agricultural industry leaders, analysts, innovative researchers, and working farmers to explore the challenges and opportunities in achieving sustainability within the agricultural sector.

I would like to extend my sincere gratitude to the CSBP, and the Farmers Golden Jubilee of Agriculture Science Fellowship for their ongoing sponsorship of this event held at UWA, which continues to be a vital platform for fostering collaboration and innovation within the agricultural industry.

In 2024, we welcomed three new members to our Board: Dr Ben Biddulph, Chief Scientist at DPIRD, Ms Carly Veitch, Farm Management Consultant at AgAsset and Mr Grey Johnston, Manager of Fertiliser Sales & Marketing at CSBP. On behalf of the Institute Advisory Board, I extend our sincere thanks to outgoing members Mr Ben Sudlow, Manager of Sales Strategy & Reliability at CSBP, Mr Philip Gardiner, and Dr Bruce Mullan, Principal Research Scientist at DPIRD, for their valued contributions.

I look forward to the IAB continuing to partner with IOA to achieve our shared goals in 2025 and beyond. Thank you to all members of the IAB, IOA contributors, and Director Hackett Professor Kadambot Siddique and his team.

Dr Terry Enright
Chair of the IOA Industry Advisory Board

As a cornerstone of The University of Western Australia's research landscape, the UWA Institute of Agriculture (IOA) plays a pivotal role in advancing the University's mission as a leading research-intensive institution.

The IOA harnesses diverse expertise from across the University to tackle some of the most pressing challenges in agricultural and environmental sustainability, food security, social impact, climate change adaptation, and data innovation. The contributions of early career researchers, particularly PhD candidates, are a key aspect of the Institute's continued success, and their excellent work is prominently featured in this report.

While University rankings are but one measure of our value, they command significant attention nationally and internationally. The IOA has been instrumental in our outstanding subject rankings. In 2024, UWA proudly retained its position as the top-ranked institution in Australia and 9th globally in Agricultural Science according to the Shanghai Academic Ranking of World Universities. This exceptional achievement underscores the depth, quality, and impact of the agricultural research conducted at UWA, much of it driven by the IOA's coordinated efforts.

The IOA Annual Research Report 2024 provides a comprehensive overview of innovative research projects and initiatives designed to address critical global challenges. The Institute actively fosters partnerships with industry, grower groups, government bodies, across Schools, with other UWA institutes and Universities worldwide to ensure that its research remains relevant and impactful. Through these collaborations and its ongoing public engagement, the Institute prioritises research with real-world implications for sustainable agriculture and food security.

I commend the IOA for its dedication in effectively communicating its research outcomes through various channels, including media outreach, social media, events, and publications. These efforts are crucial in ensuring the broader uptake of UWA's research and enhancing its visibility both within Australia and globally.

I extend my gratitude to the IOA for its significant achievements in 2024, and I look forward to seeing continued advancements in knowledge and innovation from its researchers in the years ahead.

Professor Anna Nowak
Deputy Vice-Chancellor (Research)
The University of Western Australia

Field trial at the DPIRD Katanning Research Station. See page 46

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Sustainable Cropping Systems

The Sustainable Cropping Systems theme covers all aspects of crop production, both above ground and below ground. Participants in the theme work across a broad scale, from genomics and plant physiology to crop breeding and field agronomy.

Projects are generally multidisciplinary and involve collaboration among several UWA schools, as well as with farmer groups, Department of Primary Industries and Regional Development, Western Australia (DPRID), Commonwealth Scientific and Industrial Research Organization (CSIRO), Curtin and Murdoch universities, and interstate and overseas institutions. Many projects include industry partners, such as breeding companies 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 the inclusion of postgraduate students, commonly Masters by coursework and dissertation project students and PhD students.

As is evident from the projects included in our section of the annual report, we research a broad range of crops including wheat, barley, canola, lupins, chickpea, field pea, rice and pasture legumes. New and emerging crops are also often a focus. Research is generally targeted at the dryland farming systems of WA and southern Australia. However, northern Australia and our neighbours in Asia including China, Timor Leste, Bangladesh, India and Vietnam are also included in these studies.

UWA researchers are involved in projects focussed on topical areas, including maximising sustainable yield, thermal tolerance (frost and heat), crop water use efficiency, disease susceptibility/resistance, use of UAVs, big data and precision agriculture. UWA is also 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 and speed breeding. A particular focus is placed upon 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 and nitrogen, are also a focus: root morphological, physiological, and symbiotic mechanisms are all considered. In addition, we 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, we are cognisant of the needs of the industries and farmers who will ultimately apply our research outcomes to their farming systems.

Theme Leaders

Dr Nicolas Taylor
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Professor Jacqueline Batley
School of Biological Sciences
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Aerial view of UWA Farm Ridgefield. Credit: Ana Mendigutxia Balil

Wheatbelt land-use paradigms – navigating new industries in the low carbon and natural capital era

Project team: Mrs Carla Swift[2] (Project leader; cswift@wheatbeltnrm.org.au), Mr Alex Johnson[2], Professor Marit Kragt[1], Dr Michael Young[3], Dr Kim Brooksbank[3], Mr James Shaddick[3], Mr Keith Claymore[3].

Collaborating organisations: [1]UWA; [2]Wheatbelt NRM, [3]DPIRD, [4]Farm Optimisation Group.

This project explores land use changes in Western Australia's Wheatbelt that are driven by partnerships between farmers and private companies involved in biofuels and carbon initiatives. Emerging carbon industries have identified the Wheatbelt as ideal for biomass crop production and environmental plantings, which can generate Australian Carbon Credit Units. By integrating trees on farm, producers could enhance natural capital, offset emissions, and diversify income streams while maintaining agricultural productivity.

The goal of this project is to assist landholders to navigate carbon offset schemes and environmental markets, while improving profitability and resilience to climate change.

The project will model the impacts of different tree configurations on farm economics and natural capital and will work with landholders to understand and address current knowledge gaps and information needs.

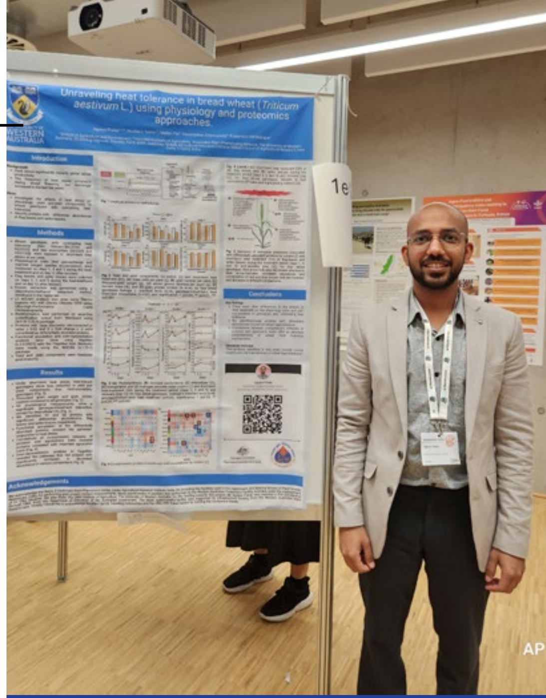
The work aims to provide a balanced discussion of the economic, environmental, and social impacts of adopting new land-use systems, focussed on building resilience in farming systems, identifying key barriers to adoption, and addressing long-term risks of private sector partnerships.

The outcomes will equip farmers with the knowledge and tools to navigate long-term partnerships, mitigate risks, and leverage environmental credentials to meet market demands and compliance frameworks.

Additionally, this work will inform regional planning and policy, supporting a robust transition to nature-positive and emissions-conscious agriculture, positioning the Wheatbelt as a leader in sustainable farming practices in a rapidly evolving low-carbon economy.

This research is supported by UWA and DAFF Climate-Smart Capacity-Building Program Grant.

Salmon Gums at sunset in the Western Australian Wheatbelt near Bruce Rock, WA (Source: CSIRO Science Image 4429)



PhD student Mr Agyeya Pratap presented the results from first experiment at international national conferences as poster and oral presentation.

Unravelling heat stress tolerance in bread wheat (*Triticum aestivum* L.) by investigating changes in leaf and spike proteomes

Project team: Hackett Professor Kadambot H.M. Siddique[1] (Project leader; kadambot.siddique@uwa.edu.au), Associate Professor Nicolas Taylor[1], Mr Agyeya Pratap[1].

Collaborating organisations: [1]UWA; [2]Indian Agricultural Research Institute; [3]Western Australian Proteomics Facility.

Heat stress is a significant threat to global wheat productivity, with rising temperatures and more frequent heatwaves affecting crop yields and grain quality. Understanding how wheat plants respond at the molecular level can provide crucial insights into heat tolerance mechanisms, ultimately aiding the development of more resilient varieties.

This study explored the physiological and proteomic responses of wheat genotypes with contrasting heat tolerance. Two heat-tolerant genotypes (RAJ3765, HD2932) and two heat-susceptible genotypes (HD2329, HD2733) were subjected to short-term heat stress at the ear peep stage. The heat-tolerant genotypes maintained grain yield by maintaining grain number, biomass, harvest index and grain protein content under short- and long-term heat treatments. The thousand grain weight increased under short-term heat treatment whereas it increased under long-term heat treatment.

Key phenology, and physiological traits, including leaf gas exchange and reactive oxygen species accumulation, over multiple time points during stress exposure and recovery were monitored. The heat-tolerant genotypes maintained normal phenology and physiology while heat-susceptible genotypes struggled to do so under the short-term heat treatment.

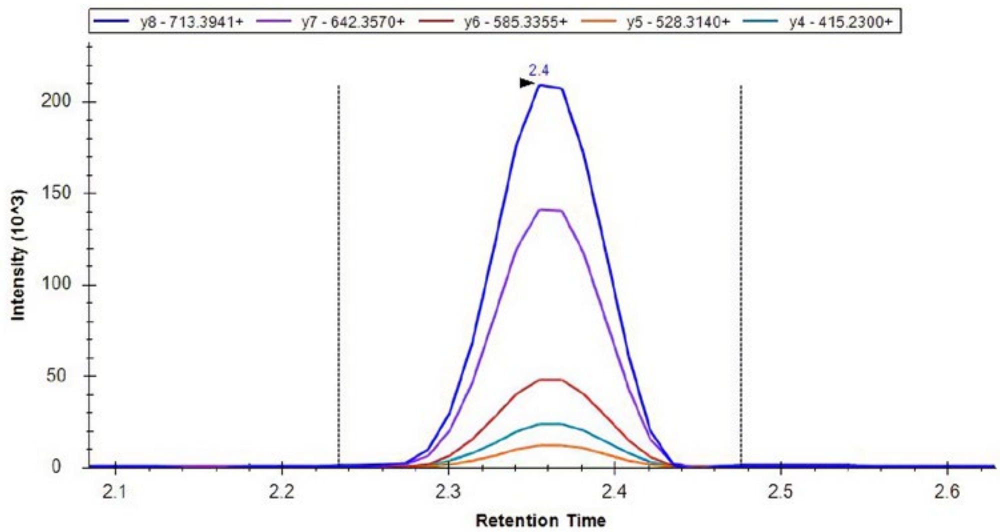
A comparative proteomic analysis flag leaves and spike tissues revealed significant differences in protein abundance between the genotypes. In total, 31 differentially abundant proteins were identified in flag leaves and 60 in spike tissues. Many of these proteins were linked to key biological pathways involved in stress adaptation, including antioxidant activity, protein folding, and cellular repair mechanisms.

These findings suggest that heat-tolerant genotypes can better maintain cellular homeostasis under high-temperature conditions by changing the abundance of proteins involved in crucial cellular processes as a heat-adaptation response. Co-expression network analysis also linked specific proteins to agronomic traits such as grain yield and thousand-grain weight, reinforcing their potential significance in breeding programs.

To further validate these results, targeted proteomics was performed on two selected genotypes: Vixen (heat-tolerant) and HD2329 (heat-susceptible). Correlations were drawn between physiology, yield and yield components, and the targeted protein abundances under heat treatment of 5 days and day 12 of recovery, like the previous experiment. This additional analysis confirmed the role of several proteins as potential biomarkers for heat tolerance.

Overall, this research provides valuable insights into the molecular basis of heat tolerance in wheat. The identification of key proteins associated with stress resilience offers promising targets for breeding programs aimed at developing heat-tolerant wheat varieties. As climate change continues to pose challenges for global food security, such advancements will be critical in ensuring stable wheat production in hotter growing conditions.

This research is supported by UWA.



Targeted mass spectrometry of a single peptide for quantification in Skyline software.

Arrow indicates a small necrotic lesion formed following second inoculation of the bottom half of cotyledon 1 of cv. Westar with L. maculans isolate P11 on day 7. Top half shows a large expanded necrotic lesion developed in the upper half of this cotyledon after first inoculation with the same isolate on day 0.

Turnip mosaic virus phenotype + consisting of severe mosaic in uninoculated cv. Westar leaves after first and second TuMV inoculations to opposite half cotyledons on day 0 and day 3, respectively.

Canola fungus-virus pathogen interaction research

Project team: Professor Martin Barbetti[1] (Project leader; martin.barbetti@uwa.edu.au), Adjunct Professor Roger Jones[1], Dr;Ming Pei You[1], Mr Nuzairat Abidin[1].

Collaborating organisations: [1]UWA.

Few recent investigations examine coinfection interactions between fungal and viral plant pathogens. This research investigated coinfections between *Leptosphaeria maculans* and turnip mosaic virus (TuMV) in canola (*Brassica napus*). *L. maculans* causes blackleg disease, canola's most important yield-limiting fungal pathogen, its spores being spread by wind and rain. TuMV is a major pathogen of *Brassica* crops and is spread mainly by aphid vectors.

The aim was to understand interactions between different combined infections, and inoculation sequences, of resistance-breaking and non–resistance-breaking *L. maculans* strains with the resistance-breaking TuMV strain when these infect cultivars with three different host resistances, *L. maculans* single-gene dominant resistance (SGR) and polygenic resistance (PGR), and TuMV temperature-sensitive invasion resistance (TSSIR).

Different combinations of *L. maculans* isolate P11 and resistance breaking isolates *L. maculans* UWA192 and TuMV 12.1 were inoculated to three canola cultivars with differing pathogen resistances/susceptibilities. They were inoculated first to entire or half cotyledons 10-12 days after emergence, and second to opposite entire or half cotyledons on the same day (day 0) or 3 or 7 days afterwards. The parameters measured were *L. maculans* cotyledon disease index (%CDI), and TuMV systemically infected leaf symptom intensity (SI) and virus concentration (VC). Except when both day 0 inoculations were with isolate UWA192, %CDI values were supressed strongly or only weakly when isolates P11 and/or UWA192 were inoculated to plants with SGR or PGR, respectively.

However, except when isolate P11 was inoculated first and UWA192 second, these values declined after inoculation day 0 when SGR was absent. TuMV infection suppressed %CDI values, although this decrease was usually smaller following day 0 half cotyledon inoculations. When TSSIR was present and both inoculations were with TuMV, SI and VC values diminished greatly. However, the extent of this decrease was reduced when second inoculations were with *L. maculans*. SI and VC values were also smaller when SGR was present and second inoculations were with *L. maculans*. When *L. maculans* resistance was lacking, SI and VC values were smaller when second inoculations to entire cotyledons were with *L. maculans* rather than TuMV. This also occurred after second half cotyledon inoculations with isolate P11 but not isolate UWA192. Therefore, diverse intra- or inter- pathogen interactions developed depending upon host resistance, isolate combination, cotyledon inoculation approach and second inoculation timing.

This study found coinfection between *L. maculans* and TuMV can play an important role in disease symptom development and the effectiveness of diverse host resistances against these two pathogens. Since individual infections with *L. maculans* or TuMV both cause major disease losses in diverse *Brassica* crops growing in different world regions, and TuMV also severely damages crops in other plant families, this study with coinfecting canola pathogens provides an important foundational step for further research on effects of co-occurring pathogens upon the effectiveness of host resistances in these and other crops.

This research is supported by UWA and BGS.

Biological properties of Turnip mosaic virus – Seed transmission in a *Brassica* species

Comparison of infected (left) and healthy (right) seedlings grown from seed lot Tendergreen A; infected seedling shows symptoms of severe mosaic and both leaf deformation and curling.

Project team: Adjunct Professor Roger Jones[1] (Project leader; roger.jones@uwa.edu.au), Professor Martin Barbetti[1], Dr Ming Pei You[1], Mr Nuzairat Abidin[1].

Collaborating organisations: [1]UWA.

Turnip mosaic virus (TuMV) causes important diseases in *Brassicaceae* crops worldwide. Its hosts include many *Brassica* crop species in addition to *B. rapa* and *B. napus*. It is long been known to be transmitted from infected to healthy plants by aphids, but it was not until 2019, i.e. almost 100 years after TuMV was first found, that definitive evidence of its seed transmission from seed-to-seedlings was reported. This was in the *Brassicaceae* model plant *Arabidopsis thaliana*.

This study now demonstrates that this also occurs in *B. rapa*. This is important because sowing virus-infected seed not only introduces seed-borne virus infection sources to crops growing in new fields on the same farm, other farms in the same district, or farms in other agricultural regions within the same country, but also via the international seed trade to farms in other countries in the same or other continents.

In 2023, *Brassica rapa* ssp. *perviridis* cv. Tendergreen seedlings with virus-like symptoms were found growing within an insect-proof glasshouse. The affected seed lot (A), three others of Tendergreen, and five belonging to other *B. rapa* subspecies, *B. juncea* or *Wasabia japonica* were sown in trays within Controlled Environment Rooms (CER's) from which other plants were absent. TuMV was detected in 10% of seed lot A seedlings but none from other seed lots. Next, seed lot A (experiment 1) or seed from Tendergreen mother plants infected with *B. napus* TuMV resistance breaking strain isolate 12.1 (experiment 2) were sown in trays. In each experiment, these trays were subdivided into two batches, one being placed inside transparent plastic boxes, each batch then being placed in different CER's. TuMV was detected in 10% and 9% of seedlings inside or outside the boxes (experiment 1), or 1% of seedlings from both situations (experiment 2). Since virus contamination by aphid vectors or contact was excluded, TuMV seed transmission was demonstrated unequivocally. A complete TuMV genome obtained from an infected seedling (isolate BRSB1, accession PQ160044) was compared with 44 other genomic sequences from TuMV phylogroup World-B. It belonged to the same subclade as Australian resistance breaking strain isolates 12.1 and 12.5 (99.9% nucleotide identities) and 10 New Zealand sequences (99.2-99.5% nucleotide identities). Therefore, this subclade may have reached Australia via New Zealand.

Research is required to establish whether seed-to-seedling transmission occurs with TuMV isolates BRSB1 and 12.1 in other *Brassica* crop species, and whether BRSB1 and the New Zealand isolates also belong to the *B. napus* resistance breaking strain. In addition, research is required to:
(i) determine whether seed-to-seedling transmission occurs with isolates from other phylogroups and the extent this explains TuMV's widespread global distribution;
(ii) establish the role of seed-to-seedling transmission in TuMV epidemiology; and
(iii) devise effective control measures and biosecurity procedures against seed-borne TuMV infection suited to crops growing in diverse regions.

This research is supported by UWA and BGS.

Cv. Tendergreen plant grown from a TuMV-infected seedling showing symptoms of leaf curling, deformation and severe mosaic (right), healthy cv. Tendergreen plant (left).

A diverse planting plot at the Multiple Ecosystem Services Experiment at UWA Farm Ridgefield.

Exploring the effects of woody plant diversity on soil carbon storage in ecological restoration

Project team: Elina Rittelmann-Woods[2] (Project leader; elina.rittelmann-woods@murdoch.edu.au), Professor Dr Rachel Standish[2], Dr Felipe Albornoz[3], Professor Raphael Viscarra Rossel[4], Dr Alexandre Pedrinho[2], Tim Morald[2], Dr Michael Perring[1,5], Dr Sebastian Fiedler[6].

Collaborating organisations: [1]UWA; [2]Murdoch University; [3]CSIRO; [4]Curtin University; [5]UK Centre for Ecology & Hydrology; [6]Technical University of Berlin.

PhD student Elina Rittelmann-Woods taking soil samples with an auger.

Enhancing carbon sequestration through land management practices is an important tool for climate change mitigation. Additionally, combating biodiversity loss is fundamental for earth stewardship and for its role in underpinning carbon sequestration and other ecosystem services. There is great potential in aligning biodiversity conservation and carbon sequestration goals in revegetation projects to combat both crises simultaneously. This requires a deeper understanding of the links between plant diversity and carbon storage. While empirical data suggests that plant diversity can enhance carbon sequestration aboveground, the effects of woody plant diversity on soil carbon storage are less understood.

In this project Multiple Ecosystem Services Experiment at the UWA Farm Ridgefield was used to test if and how woody plant diversity affects soil carbon storage. The experiment, which was planted in 2010, consists of plots with varying levels of woody species richness including monocultures of York gum and unplanted control plots. The aim was to answer the following research questions:

1) What are mechanisms underlying the potential relationship between woody plant diversity and soil organic carbon stock at this site?
2) Has tree planting on this site successfully contributed to enhanced soil organic carbon storage?

In 2024 plant surveys to record woody species survival and species richness, took size measurements of trees and shrubs, collected groundcover, plant litter and soil samples and measured bulk density and moisture of soils were conducted. Measured litter decomposition rates were also measured. The soil samples were analysed for carbon and nutrient concentrations and pH. Subsamples of the soil were frozen, and we plan to identify soil microbial communities and measure microbial biomass carbon. Collecting data on carbon inputs, microbial processes and soil characteristics allowed to test not only if woody plant diversity affects soil carbon storage at this site, but also how woody plant diversity influences overall carbon dynamics. That is, to understand the mechanisms.

The project falls under the UWA Farm Best Practice Farming Systems Project's strategic priority "Restoration of ecosystems and biodiversity". Results can inform future restoration and carbon farming projects that aspire to mitigate climate change whilst combating biodiversity loss. In particular, informing best practice regarding management of soil carbon and soil microbes in biodiverse carbon projects and the anticipated nature repair market. Outputs will also assist Traditional Custodians and their partners to make informed decisions about the opportunities available to communities when restoring Country.

This research is supported by the Australian Government through the ARC and Murdoch Strategic and International Tuition Fee Scholarship provided by Murdoch University.

The collaborators of the Wheat Nitrogen Use Efficiency project at Annual Progress Meeting 2025.

Increasing wheat nitrogen use efficiency through improved genetics

Project team: Professor A Harvey Millar[1,2] (Project leader; harvey.millar@uwa.edu.au), Dr Hui Cao [1,2], Dr Katharina Belt [1,2], Dr Samalka Wijeweera [1,2], Dr Elke Stroeher[1,2], Dr Owen Duncan [1,2], Professor Rajeev K Varshney[3],Dr Vanika Garg[3], Ms Annapurna Chitikeni[3], Dr Reyaz Mir[3], Mr Jaco Zandberg[3], Dr Weinan Xu[3], Professor Wujun Ma[3], Dr Darshan Sharma[4], Dr Hammad A Khan[4], Dr Nasir Iqbal[4], Dr Dion Bennett[5], Dr Tristan E Coram[5], Dr Cathrine H Ingvordsen[5], Dr Kefei Chen[6]; Western Australian Proteomics Facility.

Collaborating organisations: [1]UWA; [2]ARC CoE Plant Energy Biology; [3]Murdoch University; [4]DPIRD; [5]Australian Grain Technologies; [6]Curtin University.

Increasing nitrogen (N) application to boost wheat yield presents significant environmental challenges and raises production costs. Wheat is among the least efficient crops in terms of nitrogen utilization, absorbing only one-third of the applied N. Improving nitrogen use efficiency (NUE) requires a deeper understanding of the genetic mechanisms governing NUE-related traits.

Recent research from Murdoch University has highlighted the genetic complexity of NUE. In collaboration with Australian Grain Technologies (AGT) and DPIRD, Murdoch University has developed doubled haploid (DHL) wheat lines, identifying key traits linked to grain yield (GY), NUE, and grain protein content (GPC). Among these, quantitative trait loci (QTL) have been identified as positively influencing NUE and GPC without compromising yield. These QTL are now undergoing extensive analysis to pinpoint causative alleles and functional mechanisms that enhance NUE, GY, and GPC across diverse Australian field conditions.

As part of this project, the UWA team, led by Prof. A.H. Millar, is conducting biochemical analyses to further characterize the nature of the changes in NUE, GY and/or GPC that underlie these QTLs. The team specializes in utilizing analytical approaches to investigate metabolic pathways and molecular mechanisms associated with NUE. Leveraging their expertise, they will perform NUE enzyme activity assays, GPC assessments, 15N labelling studies during grain development and targeted and untargeted proteomic analyses on doubled haploid (DH) lines. These investigations contribute to identifying QTLs with superior performance in key NUE traits. The experimental material used for these studies is cultivated in UWA greenhouses and at field sites managed by AGT and DPIRD, incorporating field-based variability to enhance real-world applicability.

The UWA research team—including Dr Hui Cao, Dr Katharina Belt, and Dr Samalka Wijeweera from the ARC Centre of Excellence in Plant Energy Biology, along with Dr Owen Duncan and Dr Elke Stroeher from the Western Australian Proteomics Facility—aims to expand the study in the coming years, focusing on unexplored genetic variability and the most promising lines identified so far.

This research is supported by GRDC.

Team working on the field.

Exploring soil amelioration effects on wheat growth, nutrition, and microbial biomass carbon in sandy soil

Project team: Shompa Akter[1] (Project leader; 23867576@student.uwa.edu.au), Hackett Professor Kadambot H.M Siddique[1], Associate Professor Zakaria Solaiman[1], Dr Gaus Azam[2], Dr Sultan Mia[2], Dr M. Asaduzzaman Prodhan[2].

Collaborating organisations: [1]UWA; [2]DPIRD; [3]Department of Agricultural Extension, Ministry of Agriculture, Bangladesh.

Wheat is a key agricultural crop in WA, significantly contributing to the region's economy. However, soil acidity poses a major challenge, particularly in the wheatbelt region where over 70% of topsoils and 50% of subsoils exhibit pH levels below the recommended range of 5.5–4.8. High soil acidity, especially in subsoil layers, leads to substantial economic losses, with annual reductions in farm revenue estimated at AU$1.6 billion.

A common remedy is the application of organic and inorganic soil amendments. While many studies have investigated individual soil amendments like lime, compost, or biochar, relatively few have examined the combined effects of multiple amendments on soil properties and microbial communities. Addressing this gap is crucial for developing sustainable soil management practices in acidic sandy soils to enhance crop production. This study investigates the impact of soil amelioration on wheat growth, nutrient uptake and grain yield while assessing its effects on soil chemical properties and microbial biomass carbon.

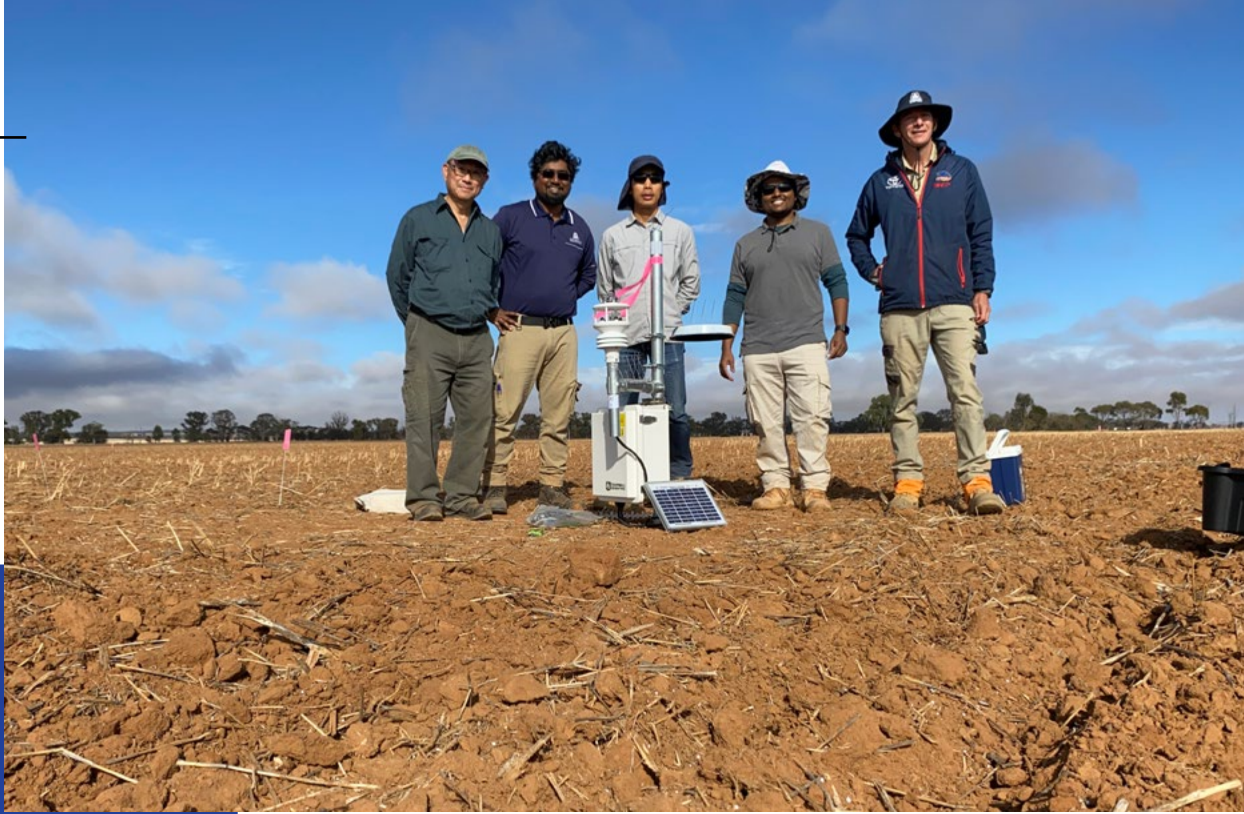
The research hypothesised that different combinations of soil amendments increase wheat yield by enhancing soil physiochemical properties and promoting diverse interactions among soil microbial communities. Undisturbed soil cores were collected for glasshouse experiment from "Re- engineering Soil" field trial in Bolgart, Western Australia (31°18′59.9″S, 116°34′37.5″E), where four soil treatments were applied three years earlier. Four soil treatments were: Control (no amendment), CLG (clay, lime, gypsum), CLG + NPK (CLG + nitrogen, phosphorus, and potassium fertilisers), and CLG + Compost. A total of 36 cores were collected, which were individually placed in 10 cm diameter, 20 cm height cylindrical PVC pots and transported to the UWA glasshouse. The study followed a completely randomised design with three replications. Wheat (cv. Scepter) was grown in 36 pots (4 treatments ´ 3 replications ´ 3 destructive harvests) to assess plant growth, nutrient uptake, soil physiochemical properties, and microbial biomass carbon at three critical stages of wheat development: vegetative, anthesis, and physiological maturity.

The results showed that combining organic and inorganic amendments improved plant growth, nutrient uptake, grain yield and nutrient status. These amendments also enhanced soil chemical properties, microbial biomass carbon and microbial composition. This study contributes to amelioration of acidic soil supporting sustainable agricultural practices and providing insights into the combined effects of organic and inorganic amendments in sandy soil. Further studies should explore the long-term effects of these amendments, their suitability for various soil types and cropping systems, and their potential to mitigate stress effects due to climate change.

This research is supported by UWA and DPIRD.

Hackett Prof. Kadambot Siddique explained the effect of soil amendments while visiting the glasshouse experiment with the supervisory team.

Microbiome metagenomics analysis at UWA plant biology lab with guidance of Dr. Sultan Mia and Dr. Asaduzzaman Prodhan.



UWA and DPIRD staff collaborating to meet project objectives. From left to right: Yoshi Sawada (UWA), Bidhyut Banik (DPIRD), Tan Dang (UWA), Md Shahinur Rahman (DPIRD), and Paul Damon (UWA).

Predicting nitrogen cycling and losses in Australian cropping systems – Western regions

Project team: Associate Professor Louise Barton[1] (Project leader; louise.barton@uwa.edu.au), Dr Craig Scanlan[2], Mr Paul Damon[1], Dr Tan Dang[1].

Collaborating organisations: [1]UWA; [2]DPIRD.

Optimising nitrogen fertiliser use is crucial, as it is both an expensive input for crop production and the largest variable cost for Australian growers. There are significant knowledge gaps regarding nitrogen (N) supply and loss pathways from modern Australian dryland grain cropping soils. These gaps need to be addressed before crop models can predict the fate of nitrogen fertiliser applied to cropping systems.

A national project funded by the GRDC aims to improve understanding and model the fate of nitrogen fertiliser. This is being achieved through three main objectives: (i) quantifying the fate of nitrogen fertiliser during the growing season and beyond the year of application at 12 national locations using ^{15}N-labelled urea; (ii) improving understanding of the nitrogen supplied from residue decomposition and soil nitrogen mineralisation; and (iii) integrating the findings into the APSIM crop-soil simulation model.

In WA, ^{15}N-labelled urea was applied to crops at four locations in 2023 and 2024: Esperance, Merredin, UWA Farm Ridgefield at Pingelly, and Wongan Hills. Using ^{15}N-labelled urea will allow the nitrogen fertiliser to be tracked through the soil-plant system for up to three consecutive growing seasons. The Merredin site also includes an additional experimental block receiving supplemental irrigation to increase crop nitrogen demand, located next to the rainfed site. Ammonia volatilisation experiments using passive samplers to measure gaseous ammonia gas loss began in 2024 at Merredin and Wongan Hills, adjacent to the ^{15}N experiments.

Preliminary results from 2023 show that nitrogen fertiliser removal in wheat grain ranged from 7 to 25 kg N/ha. The lowest removal was at the rainfed site at Merredin (Decile 1 growing season), while the highest was at Pingelly and Esperance (Decile 9 growing season). The proportion of applied nitrogen fertiliser removed in grain ranged from 21 to 25% at the rainfed sites, increasing to 39% at Merredin when supplementary irrigation was applied.

New equipment and monitoring techniques for measuring ammonia volatilisation losses were successfully implemented in Western Australia in 2024. Early results indicate that ammonia volatilisation losses over a three-week period represented less than 5% of the nitrogen fertiliser (urea) broadcast onto the soil shortly after sowing.

A national project, using ^{15}N-labelled urea to track nitrogen fertiliser dynamics for up to three consecutive cropping seasons, is well underway and will run until mid-2026.

This research is supported by GRDC, Agriculture Victoria, CSIRO, Murdoch University, NSW Department of Primary Industries and Regional Development, Queensland Government, Queensland University of Technology, SARDI, The University of Queensland, UWA and DPIRD.

Aerial view showing ammonia volatilisation being measured using passive samplers fitted to a mast in the center of a circular plot (50m diameter) at Wongan Hills.

Decoding the language of parasitic plants: understanding the interaction between *Pilostyles* and its hosts

Pilostyles of D. decurrens.

Daviesia divaricata in bloom.

Project team: Professor Jacqueline Batley[1] (Project leader; jacqueline.batley@uwa.edu.au), Dr Aria Dolatabadian[1].

Collaborating organisations: [1]UWA.

Pilostyles is an example of an incredibly extreme form of plant parasitism known as endoparasitism. They bend the rules on what we consider a plant. Understanding such a plant is an important evolutionary perspective as to what drives it to form this symbiosis and what it takes to maintain it. This parasitism lends itself to various levels of host specificity, geographical restrictions, and difficulty in *in-vitro* culture.

Pilostyles has been an enigma of a plant for decades, relatively unknown to many, but passionately researched by botanists who do. This project aims to understand how to propagate *P. hamiltoniorum*. Seeds have been challenging to work with, as they have been for many years. Strigolactones, smoke water, varying temperatures, and after-ripening methods have all been tried so far, but with no results. Stem cuttings have become the potential means for a more straightforward method of establishing an *ex-situ* culture.

Along with the propagation of the species, the study has so far managed to show that there is some within-species host preference, as *P. hamiltoniorum* is specific to ten species of *Daviesia*. The goal is to see if there is an equal preference for a host or a preserved preference for one or a few hosts over others. This resulted in a preference for certain species depending on the site and a particular host, *Daviesia decurrens*, consistently showing to be the least preferred. This research highlights that something is occurring within the hosts that leads some to be more proffered over others. Is it genetic, or just the luck of a seed close by?

To understand the interaction at play and further understand the evolution of endoparasitism in *Pilostyles*, a genome of *P. hamiltoniorum* will be assembled; this will allow to look at what gene families are present and what have been deleted, as endoparasitic plants are known to high levels of gene loss. This genome will also allow to compare *Pilostyles* to other endoparasites and other parasitic plants to help continue adding to the story of the evolution of parasitism within plants.

This research is supported by Holsworth Wildlife Research Endowment.

Modifying plant sterol metabolism to combat insect pests for crop protection

Project team: Professor Jacqueline Batley[1] (Project leader; jacqueline.batley@uwa.edu.au), Dr Jing Li[1], Ms Jelena Um[1,2].

Collaborating organisations: [1]UWA; [2]Nagoya University; [3]Murdoch University.

Canola (*Brassica napus*) is an important crop globally, particularly for Australian agriculture and economy. However, insect pests cause millions of dollars in damage every year worldwide.

This study proposes a solution based on phytophagous insects' inability to utilise all sterols to produce their own sterols and moulting hormones. Sterol biomolecules in cellular membranes can act as precursors and signalling molecules in various bioprocesses, including plant and insect growth.

This investigation aims to produce novel sterol profiles in canola that confer protection towards phytophagous insects by utilising existing knowledge about the sterol pathway genes and discovering the effect of gene mutations on the sterol profile and phenotype of the Brassicaceae family.

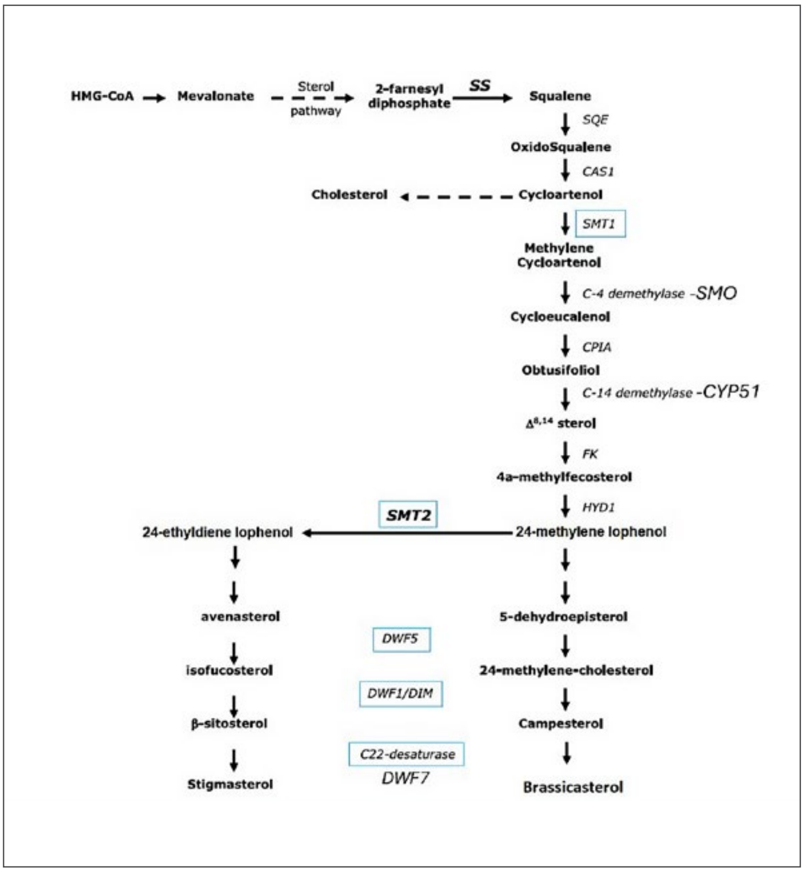
This will be achieved through multiple steps, starting with analysing a Targeting Induced Local Lesions in Genomes (TILLING) mutant population of *Brassica rapa* in search of a mutant sterol profile that presents the necessary conditions for insect protection. Upon analysis of mutants of interest, genome editing and transformation techniques will be performed in canola based on the genetic and phenotypic information gathered. All mutants and transgenic plants will be subject to insect-feeding studies to demonstrate the validity of the experiments.

In 2024, the TILLING population analysis began, with all the relevant lines ordered, received and planted, and all leaf samples collected from the specimens. The bulking of these lines was also completed, with all new seeds collected. Preparation and optimisation of the sterol analysis via GC-MS has been started and is predicted to be finalised in 2025. The work for generating knockout mutants of different genes in the sterol line has also been started. They will be generated via CRISPR technologies and protoplast generation to create a transgene-free, transient transformation of canola.

This project will provide a more sustainable way to tackle insect pest management, allowing fewer pesticides to be used in the field while maintaining high yields. Plant breeders can take up the results of this research and use them in canola for insect-resistant strains. Eventually, the rationale behind this research can be extended to multiple crops.

This research is supported by GRDC and ARC.

TILLING population growing in UWA's Glasshouse Facilities.



Schematic representation of the sterol pathway in higher plants.

The potential of Planet satellite data for weed patch detection in Western Australian cropping fields

Project team: Dr John Duncan[1,2] (Project leader; john.duncan@uwa.edu.au), Leah Daymond[1,2], Professor Ken Flower[1,2], Dr Mike Ashworth[1,2], Dr Monica Furaste Danilevicz[1,2].

Collaborating organisations: [1]UWA; [2]Australian Herbicide Resistance Initiative.

Weed detection for site-specific weed management (SSWM) via satellites has been proven to be limited by both spatial and temporal resolution. The recent introduction of commercial micro-satellite products, like Planet's PSB.SD, offer the potential to detect weeds through higher spatial resolution (3m), multiple spectral bands and sub-daily captures.

This pilot-study explores the viability of using Planet's micro-satellite to detect weeds at different growth stages within Western Australian cropping systems.

Ground truth data was collected by mapping patches of varying weed presence and densities, using high-precision differential GPS and mobile GIS mapping software in the summer fallow and at various crop-stages; summer fallow weeds, in-crop early post-emergent and crop-elongation (winter weeds).

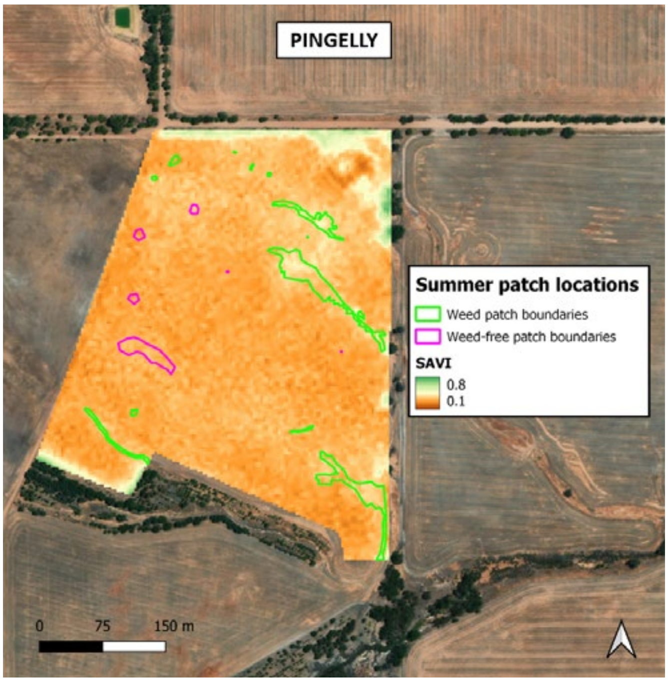
This data was then combined with temporally matched, multi-spectral Planet images and time-series to explore if weed signatures were present in fallow ('green-on-brown' (GoB)) and in-crop ('green-on-green' (GoG)) via exploratory data analysis, visualisation techniques and statistical analyses.

Summer results indicated clear differences between weed and weed-free patches, whilst also highlighting the importance of capturing multiple images over time to detect when weeds are present in fields. In contrast, GoG detection in winter was more complex. However, the results do suggest potentially useful spectral characteristics of weeds; including a low red-edge chlorophyll index and increased near-infrared reflectance, as weed density increases. Again, the study demonstrated the importance of utilising time series analysis, as weed patches were distinguishable at some crop stages and not at others.

This exploratory study indicates the potential to detect weeds using Planet micro-satellite imagery, maximising Planet's high spatio-temporal resolution. This could create opportunities for generating regional-scale, high temporal and spatial resolution maps of weed presence for SSWM.

This research is supported by GRDC and UWA.

Mapping weed and weed-free patches in the field with the EMLID GPS rover, which was linked to a nearby base station to provide centimetre accuracy.



Boundaries of the observed weed and weed-free patches overlaying a soil-adjusted vegetation indices map, at the UWA Ridgefield farm near Pingelly.

Exploring cloned disease resistance gene homologues and resistance gene analogues in *Brassica nigra, Sinapis arvensis,* and *Sinapis alba*

Project team: Professor Jacqueline Batley[1] (Project leader; jacqueline.batley@uwa.edu.au), Dr Aria Dolatabadian[1], Dr Junrey Amas[1], Dr William Thomas[1], Dr Mohammad Sayari[2], Dr Hawlader Abdullah Al-Mamun[1], Professor David Edwards[1].

Collaborating organisations: [1]UWA; [2]University of Manitoba, Canada.

Plant diseases pose a major challenge to global agriculture, threatening crop yields and food security. Understanding the genetic basis of disease resistance is essential for breeding more resilient crops. Resistance gene analogues (RGAs) are key components of plant defence mechanisms, and their identification in *Brassica* species can provide crucial insights into disease resistance at the molecular level.

This study aims to comprehensively analyse the RGA landscape in *Brassica nigra, Sinapis arvensis*, and *Sinapis alba* genomes. The specific objectives are:

- Utilise the RGAugury pipeline for the identification and classification of RGA.
- Examine the distribution and density of RGAs across chromosomes, focusing on understanding the spatial organisation of different RGA types.
- Identify homologous genes among both RGAs and non-RGAs in each species to understand the broader genetic context of disease resistance.
- Analyse the co-localisation of RLKs and RLPs within reported disease-resistance loci in *Brassica* crops.
- Perform phylogenetic analysis of cloned RGAs and QTL-mapped RLKs and RLPs to uncover distinct clusters.

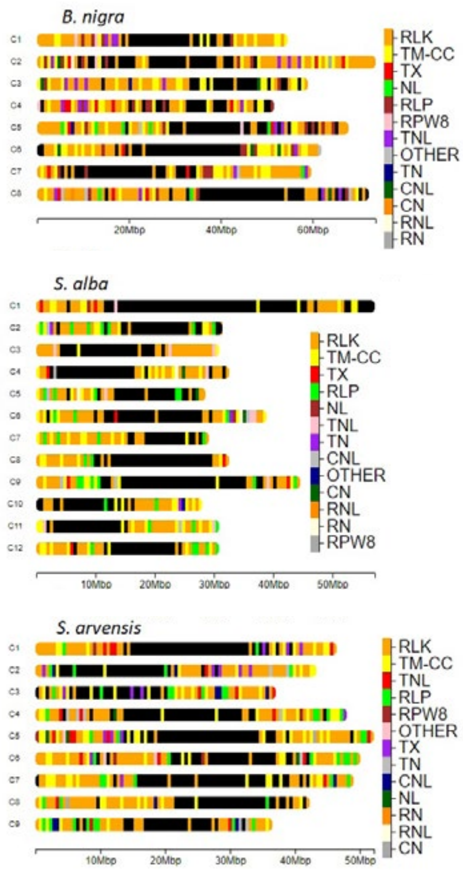
A total of 4,499 RGAs were identified across the three genomes, with RLKs being the most abundant, followed by TM-CCs and RLPs. Sub-classification of RLKs and RLPs revealed the presence of LRR-RLKs, LRR-RLPs, LysM-RLKs, and LysM-RLPs. Additionally, atypical NLRs were more prevalent than typical NLRs across all three species.

The study investigated the distribution of RGAs across chromosomes, revealing that they are predominantly located near chromosome ends. The relationship between chromosome size and RGA abundance varied among species: in *B. nigra* and *S. arvensis*, larger chromosomes generally contained more RGAs, while in *S. alba*, larger chromosomes often had fewer RGAs, though exceptions were observed. Pairwise similarity analyses of RGAs uncovered distinct gene clusters, highlighting evolutionary relationships.

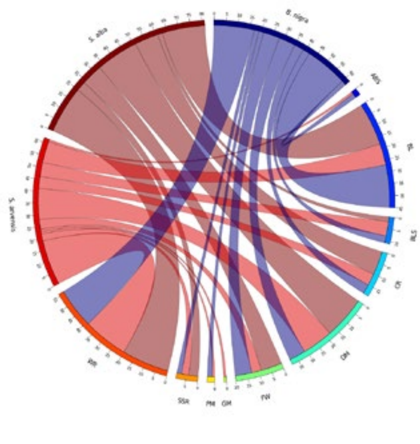
Furthermore, homologous genes were identified between RGAs and non-RGAs. The co-localisation of RLKs and RLPs within previously reported disease resistance loci in *Brassica* species revealed significant associations, suggesting their involvement in plant immunity. Phylogenetic analysis of cloned RGAs and QTL-mapped RLKs and RLPs further clarified evolutionary relationships, identifying distinct gene clusters.

These findings enhance our understanding of RGA diversity, distribution, and evolutionary patterns in *B. nigra, S. arvensis,* and *S. alba.* By providing insights into the genetic architecture of disease resistance, this study contributes valuable knowledge for future research in plant immunity and crop improvement. The results have important implications for breeding disease-resistant *Brassica* crops, ultimately supporting efforts to enhance global food security.

This research is supported by UWA and University of Manitoba, Canada.



Different types of RGAs show varying distribution patterns along the chromosomes, in B. nigra, S. alba and S. arvensis.



The number and distribution of cloned disease resistance gene homologues associated with resistance to various diseases, including Alternaria black spot (ABS), blackleg (BL), bacterial leaf spot (BLS), clubroot (CR), downy mildew (DM), Fusarium wilt (FW), grey mould (GM), powdery mildew (PM), Sclerotinia stem rot (SSR), and white rust (WR) in the genomes of B. nigra, S. arvensis, and S. alba.

Timing of glyphosate application determines white leaf spot disease severity on glyphosate-tolerant canola

Project team: Professor Martin Barbetti[1] (Project leader; martin.barbetti@uwa.edu.au), Yan Ai[1], Dr Ming Pei You[1], Dr Guijun Yan[1].

Collaborating organisations: [1]UWA; [2]University of Manitoba, Canada.

Canola (*Brassica napus*) production in Australia widely utilises glyphosate-tolerant [Roundup Ready® (RR)] cultivars. White leaf spot (*Neopseudocercosporella capsellae*) significantly threatens canola globally, but particularly in Australia. Studies were undertaken on Hyola RR 500 with moderate resistance and Hyola RR 504 which is highly susceptible to white leaf spot, to determine how glyphosate application at various timings before and after *N. capsellae* infection affects white leaf spot development.

While on both cultivars glyphosate application before inoculation resulted in the greatest increases in disease severity, glyphosate application after the disease was already present, comparatively, had only minimal effect.

This study highlighted the potential significant benefit for farmers by withholding glyphosate applications until *N. capsellae* infections are well established in order to minimize predisposition to severe white leaf spot disease that occurs where glyphosate is applied prior to the main *N. capsellae* infection period.

Typical severe white leaf spot disease when glyphosate is applied early in the season before the disease develops (A); much less severe disease when glyphosate is applied later in the season and after white leaf spot disease has appeared (B).

Atrazine application shapes white leaf spot disease development on triazine-resistant canola

Project team: Professor Martin Barbetti[1] (Project leader; martin.barbetti@uwa.edu.au), Yan Ai[1], Dr Ming Pei You[1], Dr Guijun Yan[1].

Collaborating organisations: [1]UWA; [2]University of Manitoba, Canada.

White leaf spot disease (*Neopseudocercosporella capsellae*) is an important disease on canola (*Brassica napus*) in Australia with in-field seed yield losses of up to 24%. Studies were undertaken on two atrazine-tolerant canola cultivars (moderately resistant Crusher TT and highly susceptible Thunder TT) to white leaf spot to determine how atrazine application affects development of this disease.

There were significant main treatment effects in relation to disease incidence and severity from atrazine spray both before and after the disease was present, but with greatest disease suppression from atrazine application prior to the disease being present. That the extent of disease suppression by atrazine application was substantial and that it varied with cultivar susceptibility, application timing, and that there was a strong interaction of cultivar x application timing, highlights potential opportunities for farmers.

Such opportunities include exploiting better cultivar choices in conjunction with manipulating the timing of atrazine application, to be earlier in the season before white leaf spot disease develops, that together should maximize both suppression of white leaf spot disease and the consequent canola yield.

This research is supported by UWA.

PhD student Mr Yan Ai in the glasshouse assessing white leaf spot disease development on triazine-resistant canola.

Effect on greenhouse gas emissions (CH_4 and N_2O) of straw mulching or its incorporation in farmland ecosystems in China

Project team: Xiaoliang Qin[2] (Project leader; qinxiaoliang@nwsuaf.edu.cn), Tiantian Huang[2], Shuyue Wen[2], Maoxue Zhang[2], Yanyu Pan[2], Xiaoping Chen[2], Xuan Pu[2], Miaomiao Zhang[2], Pengfei Dang[2], Min Meng[2], Wen Wang[3], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]Yulin University, China.

This meta-analysis examines the impact of straw returning methods—straw mulching (SR-M) and straw incorporation (SR-I)—on greenhouse gas (GHG) emissions in China's farmland ecosystems. While straw returning enhances soil carbon sequestration and crop yield, it also influences CH_4 and N_2O emissions, with the extent of impact varying based on environmental and management factors.

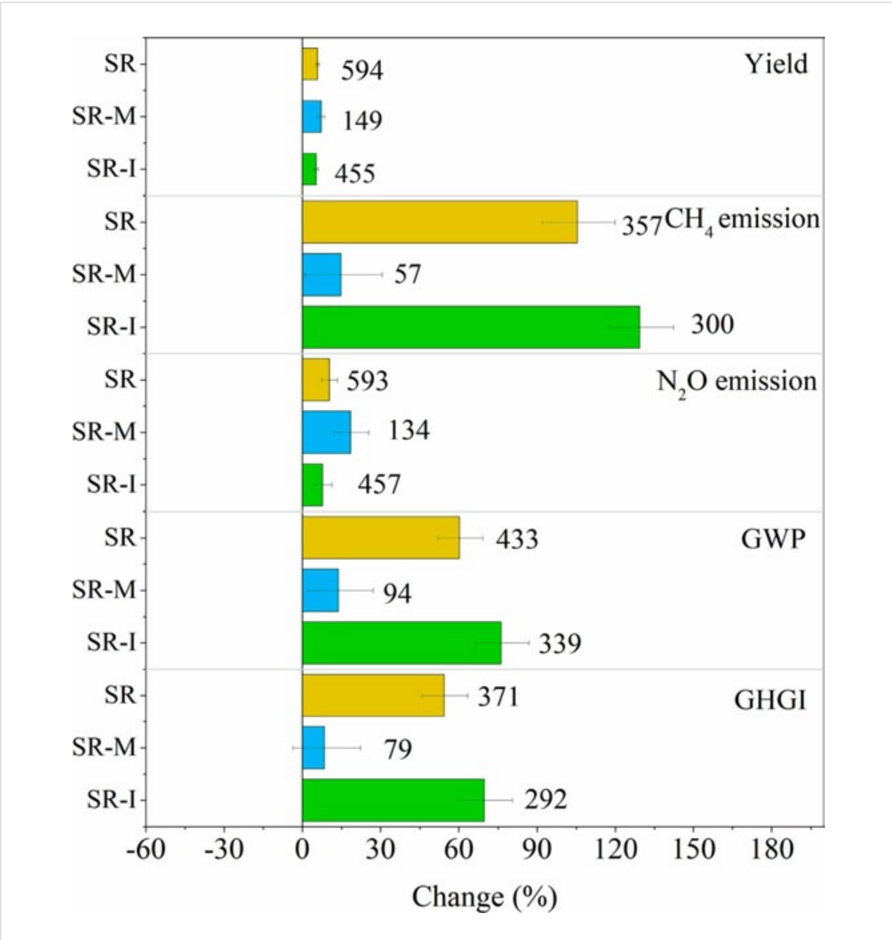
The study, synthesizing data from 217 publications, found that SR-I significantly increased CH_4 emissions (129.39%) compared to SR-M (14.86%), whereas SR-M had a greater effect on N_2O emissions (18.47%) than SR-I (7.76%). However, SR-I contributed more to soil carbon accumulation. The impact of straw returning was influenced by climatic conditions, soil properties, and management practices. Under cooler temperatures (MAT ≤ 14°C) with higher precipitation (MAP > 800 mm), lower initial soil organic carbon (SOCi ≤ 14 g kg^{-1}) and total nitrogen (TNi ≤ 1.2 g kg^{-1}), and soil pH > 6, SR-M had a reduced effect on GHG emissions. Meanwhile, under similar temperatures but with lower precipitation (MAP ≤ 800 mm), higher SOCi (>14 g kg^{-1}), TNi (>1.2 g kg^{-1}), and soil pH > 8, SR-I had a lesser impact on emissions.

Long-term straw returning had a smaller effect on CH_4 and N_2O emissions compared to short-term applications, suggesting the benefits of sustained straw management. Deep straw incorporation (SR-I deep, mixing straw into soil at 20–40 cm depth) showed no significant impact on CH_4 and N_2O emissions, indicating its potential as a viable mitigation strategy.

The study recommends optimal straw application rates: SRA ≤ 6000 kg ha^{-1} with NAR > 200 kg ha^{-1} for SR-M and SRA > 6000 kg ha^{-1} for SR-I. Although SR-M had a lower impact on global warming potential than SR-I, the latter was more beneficial for long-term soil carbon sequestration. Future research should consider net global warming potential and the carbon footprint of mechanical fuel use.

These findings provide a scientific foundation for optimizing straw management practices to balance productivity and sustainability in agriculture while mitigating GHG emissions.

This research is supported by the NNSFC.



Effect of straw returning, straw mulching, and straw incorporation on crop yield, CH_4 emissions, N_2O emissions, global warming potential, and greenhouse gas intensity. Error bars and numbers in parentheses represent 95 % confidence intervals and sample size, respectively, for SR, SR-M, and SR-I.

Greenhouse gas emissions and crop-specific emission factors of eight upland crops based on a six-year field experiment in the North China Plain

Project team: Taisheng Du[2] (Project leader; dutaisheng@cau.edu.cn), Xiaolin Yang[2], Sien Li[2], Shaozhong Kang[2], Hackett Professor Kadambot H.M. Siddique[1], Professor Klaus Butterbach-Bahl[3,4].

Collaborating organisations: [1]UWA; [2]China Agricultural University, China; [3]Aarhus University, Denmark; [4]Karlsruhe Institute of Technology, Germany.

A six-year field study in the North China Plain examined greenhouse gas (GHG) emissions from eight upland crops and winter fallow periods, addressing gaps in emission data and refining crop-specific nitrous oxide (N_2O) emission factors (EFd). The study quantified direct N_2O and methane (CH_4) emissions, GHG footprints, and the influence of environmental factors on emissions.

Summer maize recorded the highest cumulative soil N_2O emissions (5.07 kg N ha−1) and average flux (225.3 μg N_2O-N m−2 h−1), exceeding emissions from spring crops, winter wheat, and ryegrass by 16–86%. In contrast, ryegrass, a cover crop, and the winter fallow period exhibited the lowest emissions. All crops acted as weak CH_4 sinks.

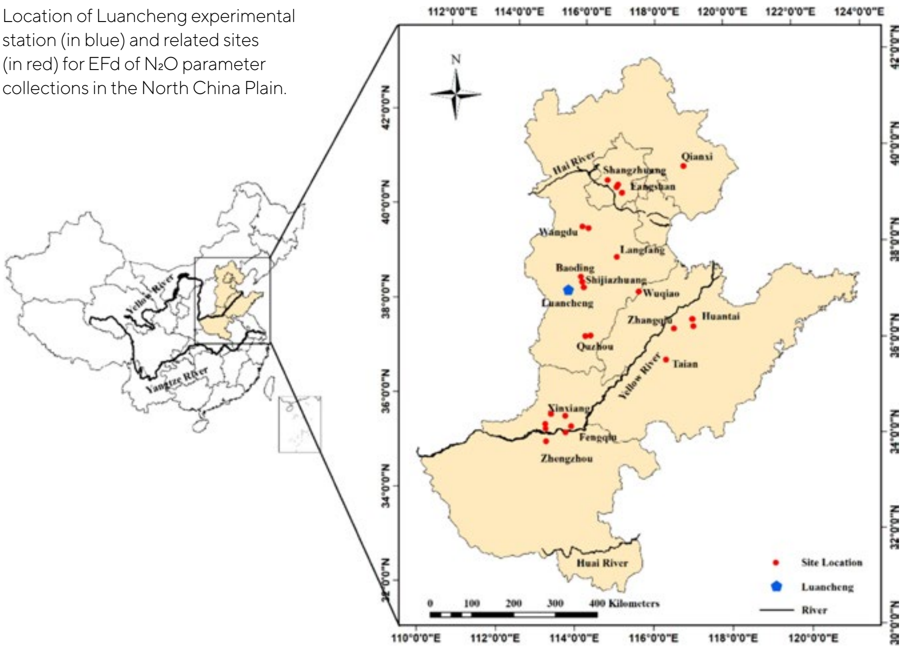
GHG footprint metrics—per unit area (GFa), per kg equivalent yield (GFy), per kg biomass (GFb), and per unit economic benefit (GFe)—showed that intensive cereal crops (winter wheat and summer maize) had the highest footprints, while sweet potato had the lowest due to higher biomass and lower nitrogen input. Other crops had 19–90% lower footprints than wheat and maize.

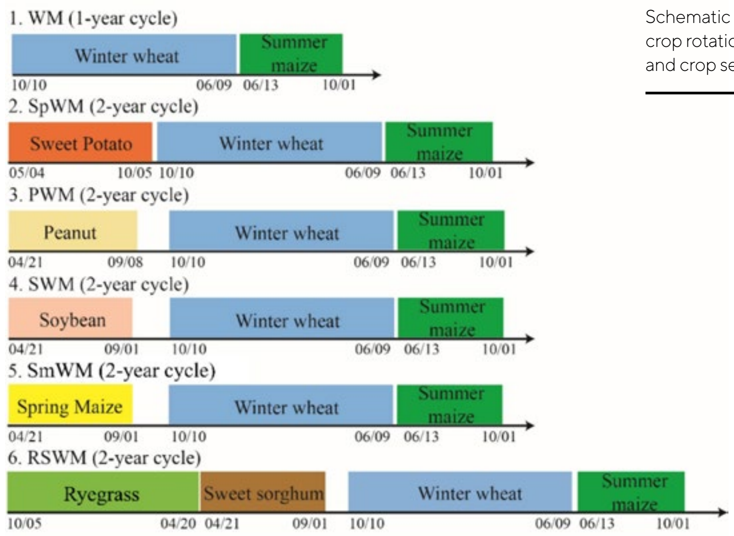
Crop-specific EFd values revealed ryegrass as the most efficient in mitigating N_2O emissions (0.48 ± 0.02%), followed by winter wheat (0.81 ± 0.43%) and soybean (1.00 ± 0.13%). The remaining crops ranged from 1.78 ± 0.43% to 2.36 ± 0.85%. Peak N_2O emissions coincided with nitrogen fertilization and high soil moisture, particularly in summer maize and winter wheat.

The study highlights the potential of cover cropping to replace fallow periods, reducing evaporation without increasing direct GHG emissions. Findings contribute critical data for improving GHG emission estimates and guiding sustainable agricultural practices in the North China Plain.

This research is supported by the NNSFC.

Location of Luancheng experimental station (in blue) and related sites (in red) for EFd of N_2O parameter collections in the North China Plain.





Schematic diagram of crop rotation design and crop sequences.

Nutrient requirements determined by grain yield and protein content to optimise N, P, and K fertiliser management in China

Project team: Zhaohui Wang[2] (Project leader; w-zhaohui@263.net), Xuemei Zhang[2], Zikang Guo[3], Junfeng Xu[2], Cui Huang[2], Haiyan Dang[2], Wenyan Mu[2], Lulu Zhang[2], Saibin Hou[4], Ning Huang[2], Chao Li[5], Yulan Ding[2], Ruiqing Sun[2], Xiaohan Li[2], Gang He[2], Jinshan Liu[2], Hackett Professor Kadambot H.M. Siddique[1].

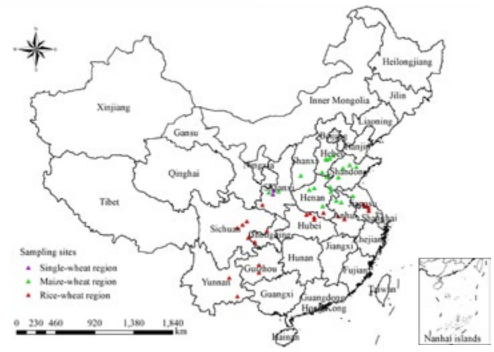
Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]Hebei Normal University of Science and Technology, China; [4]Southern University of Science and Technology, China; [5]Yunnan Agricultural University, China.

A study conducted from 2016 to 2020 across three ecological regions of China explored the nutrient requirements for wheat production, considering both grain yield and protein content. Existing research typically focuses on nitrogen (N), phosphorus (P), and potassium (K) requirements related solely to grain yield, neglecting the critical factor of grain protein content. This study aimed to address that gap by examining nutrient needs across multiple wheat cultivars and locations.

The study found that wheat grain yield ranged from 4.1 to 9.3 Mg ha–1, with an average of 6.9 Mg ha–1, and grain protein content ranged from 98 to 157 g kg–1, with an average of 127 g kg–1.

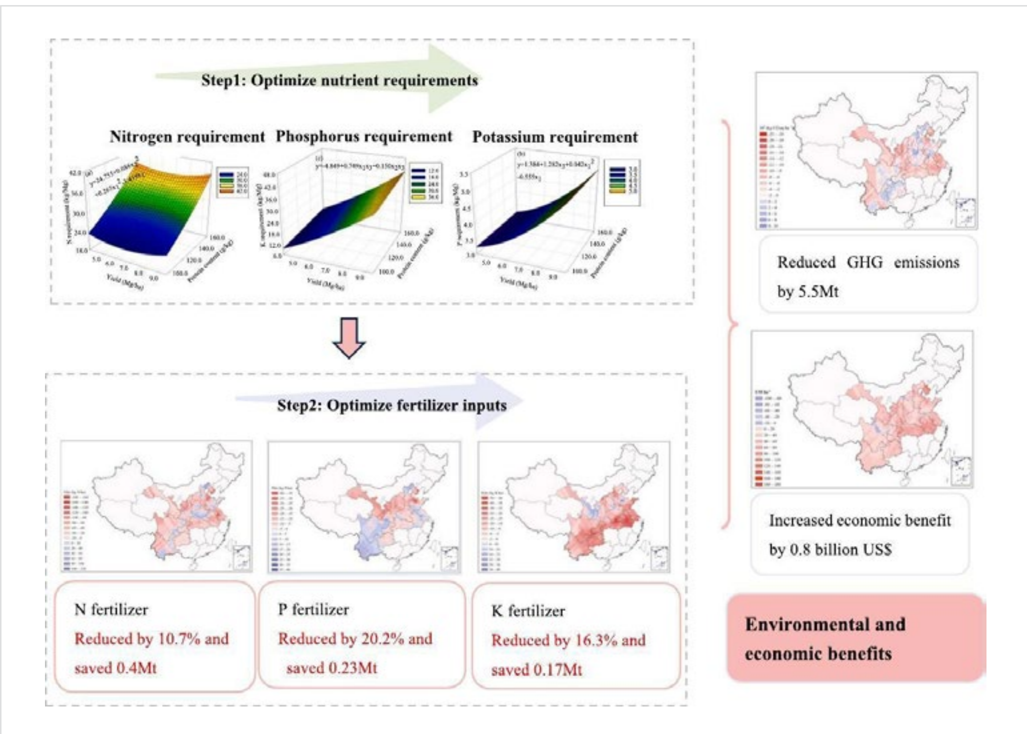
The nitrogen requirement showed a nonlinear correlation with grain yield, while it increased linearly with grain protein content. Both P and K requirements were positively correlated with grain yield and protein content. To quantify these relationships, the researchers developed regression models to predict nutrient requirements (MENR) based on varying yields and protein content.

Using MENR-based fertiliser recommendations resulted in significant reductions in fertiliser use: 22.0 kg ha–1 N (10.7%), 9.9 kg ha–1 P (20.2%), and 8.1 kg ha–1 K (16.3%). These reductions could lead to substantial environmental benefits, including a 5.5 Mt reduction in CO_2 emissions. The economic benefit of these optimised fertiliser practices was estimated at 0.8 billion USD annually across wheat production regions in China.



The findings highlight the importance of incorporating both grain yield and protein content when determining nutrient requirements for wheat. By optimising fertiliser use, farmers can achieve higher yields, improve grain protein content, and reduce overfertilization, thereby mitigating environmental risks and boosting economic returns.

This research is supported by the China Agricultural Research System and the National Key Research and Development Program of China.



Above image: Distribution of field experimental sites in wheat-growing regions of China in 2017 and 2020.

Left image: Graphical Abstract.

Incorporating straw-derived biochars enhances soil nitrogen accumulation and mitigates nitrogen leaching to facilitates crop productivity of mulching farmland in semiarid regions

Project team: Professor Peng Zhang[2] (Project leader; pengzhang121@hotmail.com), Yuhao Wang[2], Mengjie Zhang[2], Zhonghong Tian[2], Jialin Yang[2], Jinwen Pang[2], Yujing Fang[2], Enke Liu[3], Tie Cai[2], Xiaolong Ren[2], Zhikuan Jia[2], Hackett Professor Kadambot H.M. Siddique[1], Weijun Zhang[4].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]Chinese Academy of Agricultural Sciences, China; [4]Crop Research Institute, Ningxia Academy of Agricultural and Forestry Sciences, China.

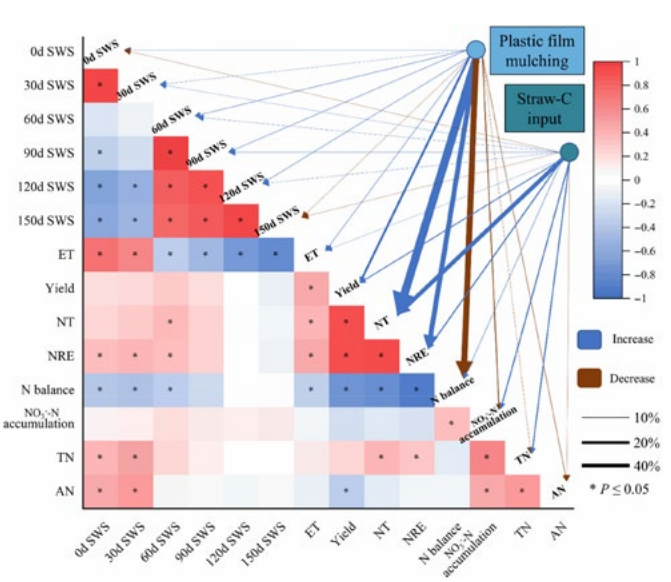
This study examined the long-term effects of straw and biochar incorporation on soil water retention, nitrogen utilization, and maize yield in film-mulched farmland in northwest China. Over five years (2017–2021), a field experiment compared six treatments: flat planting without mulching (NN), flat planting with straw (NS) or biochar incorporation (NB), film mulching alone (MN), and film mulching with straw (MS) or biochar (MB). The objective was to determine whether these amendments could enhance water use efficiency (WUE) and nitrogen recovery efficiency (NRE) while improving maize productivity in semiarid conditions.

Findings from the 2020–2021 growing seasons showed that both straw and biochar incorporation improved soil moisture retention and nutrient availability. The MB treatment significantly reduced nitrate accumulation in deep soil layers (by 28.37% compared to MN) while increasing total and alkali-hydrolyzable nitrogen content. The MS and MB treatments also improved maize nitrogen transport and grain contribution rates, with MB showing the highest increases (28.00% and 31.69%, respectively).

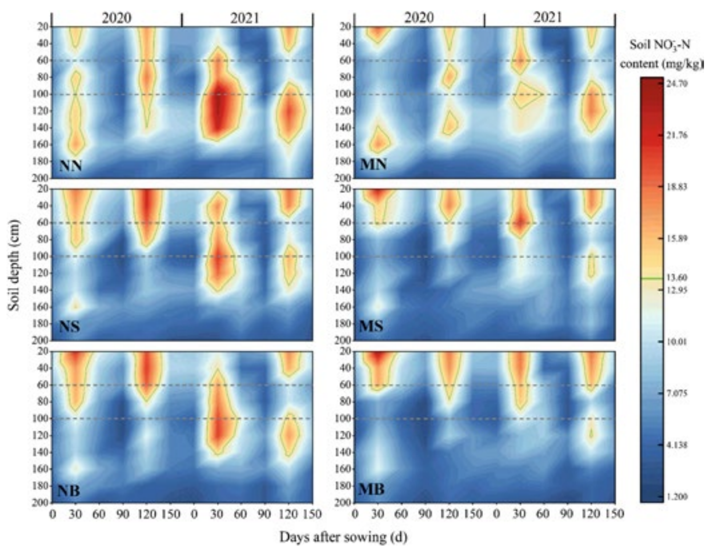
Straw and biochar incorporation enhanced WUE, NRE, and maize yield by 9.62%, 9.14%, and 14.6%, respectively, compared to MN. While both treatments contributed to improving soil fertility, biochar was particularly effective in increasing nitrogen retention, reducing leaching, and promoting aboveground biomass production. The MB treatment demonstrated superior results in maintaining nitrogen accumulation in the surface soil while preventing deep leaching, making it the most effective strategy for sustaining crop productivity in dryland farming.

Overall, these findings highlight the benefits of integrating biochar with film mulching to enhance nitrogen use efficiency and maize yields in semiarid regions. Biochar incorporation presents a sustainable approach to improving soil health and ooptimising resource utilization in dryland agricultural systems.

This research is supported by NNSFC, National Key Research and Development Program of China, Natural Science Basic Research Plan in Shaanxi Province of China, and the Ningxia Key Research and Development Program.



Correlation analysis. The figure shows the correlation between parameters (heat map on the left) and changes in these parameters by plastic film mulching and straw/biochar returning (lines on the right). Percentage change was calculated using no-mulching as the control for plastic film mulching and no-returning as the control for straw/biochar returning.



Soil nitrate-N content from 0 to 200 cm depth over time under different treatments in 2020–2021.

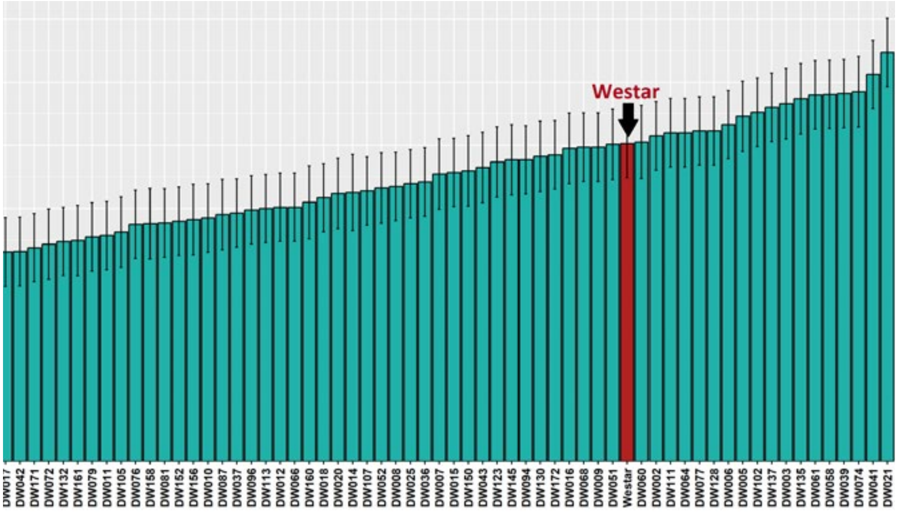
Identifying quantitative resistance against blackleg in canola

Project team: Professor Jacqueline Batley[1] (Project leader; jacqueline.batley@uwa.edu.au), Dr Thomas Bergmann[1], Dr Junrey Amas[1], Dr William Thomas[1], Dr Aria Dolatabadian[1], Dr Angela Van de Wouw[2], Professor Dave Edwards[1].

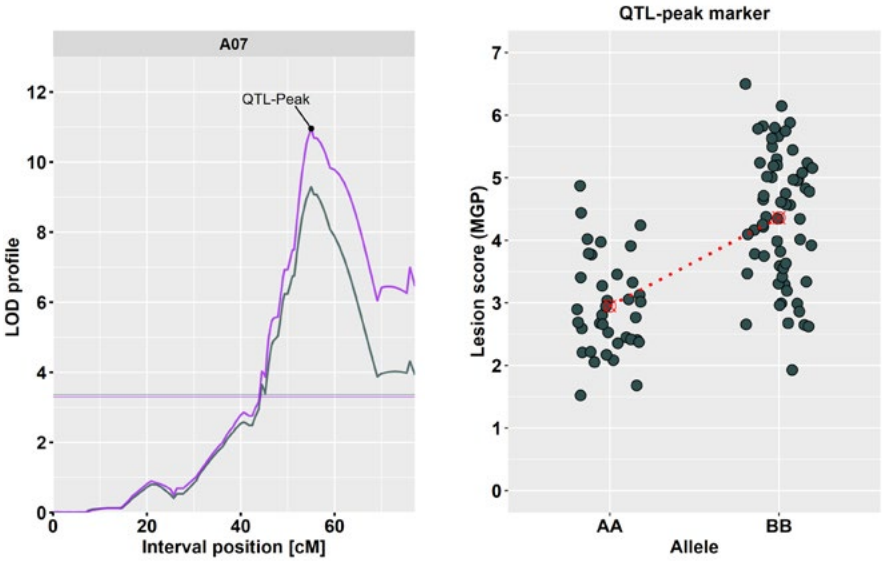
Collaborating organisations: [1]UWA; [2]University of Melbourne.

Blackleg remains a major constraint in canola production in Australia. Whilst the deployment of major *R* genes has been considered as the cornerstone of blackleg management, this has also encouraged the pathogen to rapidly evolve, making it more virulent than ever before. This increase in virulence is rendering most of the known blackleg *R* genes less effective and making disease control more challenging to implement over time. This has shifted attention toward quantitative resistance (QR), which has been known to be more durable due to the cumulative genetic effects of the many genes that underpin this type of resistance. However, due to its complexity, efforts to characterise QR in canola have been limited. In this project, we aimed to identify sources of blackleg QR and subsequently pinpoint the causative genomic regions and genes controlling this trait to help design molecular markers for industry.

We identified the cultivar Darmor to have high levels of QR. To enable genetic mapping studies, Darmor was crossed to a susceptible line, Westar, to produce a doubled-haploid (DWDH) mapping population. The DWDH progenies were screened in Horsham, Victoria and Canberra, ACT for their responses to blackleg focusing on different QR phenotypes including hypocotyl collapse score, cotyledon infection score and stem canker severity. Initial genetic mapping detected a total of nine significant QTL regions on six chromosomes (A01, A02, A06, A07, C05 and C06) of canola. Six of these QTLs were detected from the phenotypic data recorded in Horsham, Victoria and three were detected from the data recorded in Canberra, ACT.



Transgressive segregation in Darmor x Westar doubled haploid (DWDH) progenies for cotyledon score.



Left: Logarithm of odds (LOD) profile for the adjusted cotyledon infection score recorded in Horsham, Victoria on chromosome A07. Gray = LOD profile from the single-QTL scan. Purple = LOD profile from the final multiple QTL-model. Right: Boxplot showing the effect of the identified QTL on chromosome A07. AA = Darmor alleles, BB = Westar alleles. Red dots indicate imputed phenotypes.

Furthermore, six QTLs were detected for canker severity, two for cotyledon score and one for hypocotyl collapse score.

Three of the nine QTLs were detected on chromosome A06 controlling hypocotyl collapse (1 QTL) and stem canker severity (2 QTLs). Interestingly, the two QTLs for stem canker severity were mapped to almost the same genomic region, despite the QR phenotype being measured in two different locations. This suggests that this genomic region on chromosome A06 is a stable region for blackleg QR. Two QTLs on chromosome A07 controlling cotyledon score and canker severity also overlapped. These QTLs explain relatively large phenotypic variances at 37 and 41.7%, respectively, indicating they are important targets for improving blackleg QR. The other QTLs were found on chromosomes A01 (canker severity), A02 (cotyledon score), C05 (canker severity) and C06 (canker severity).

Further validation of these QTLs is being carried out through a series of experiments, including testing their consistency across a larger number of individuals. For this, kompetitive allele specific PCR (KASP) markers have been designed for each of the QTLs for genotyping more DWDH progenies. The genotypic data from this test will be used to further narrow-down the QTL intervals, which will facilitate the identification of candidate genes. This will allow for the functional validation of these genes and development of highly accurate molecular markers that can be used for breeding. The identification of these genes and markers will reinforce efforts to manage blackleg via genetic improvement of blackleg QR in canola and contribute to understanding of the mechanisms underlying quantitative disease resistance in crops.

This research is supported by GRDC.

A series of workshops about applying and producing biochar were held across Timor-Leste in 2024.

Agricultural innovations for communities - intensified and diverse farming systems for Timor-Leste (AI-Com 2)

Project team: Associate Professor Louise Barton[1] (Project leader; louise.barton@uwa.edu.au), Mr Rob Williams[1], Mrs Joaquina Barreto[4], Associate Professor David Lee[3], Associate Professor Fay Rola-Rubzen[1], Mr Luis Pereira[4], Professor Nanthi Bolan[1], Associate Professor James Fogarty[1], Associate Professor Matthias Leopold[1], Professor William Erskine[1].

Collaborating organisations: [1]UWA; [2]Timor-Leste's Ministry of Agriculture, Livestock, Fisheries and Forestry; [3]University of the Sunshine Coast; [4]Agricultural Innovations for Communities.

Many rural households in Timor-Leste struggle to generate a reliable income from agriculture, limiting their ability to improve living conditions and livelihood opportunities. The primary aim of this research is to enhance food security, labour use efficiency, and the resilience of agricultural systems in Timor-Leste, focusing on the scaling and adoption of technologies and knowledge developed in the AI-Com 1 project. This goal is addressed through four key project themes.

Theme 1 focuses on improving our understanding of agricultural soils in Timor-Leste by using existing data to identify soil constraints and propose potential solutions. In 2024, work continued to identify major soil types within three livelihood zones at the municipality level and to develop a land capability assessment approach. Amending agricultural soils with biochar is a recognised approach to boosting crop yield in Timor-Leste. Consequently a 'Biochar Collective' was formed in 2024, and a series of training workshops on biochar production were conducted across the country.

Theme 2 aims to intensify agricultural production by developing conservation agriculture methods and exploring alternative legumes for maize systems. A set of on-farm experiments investigated if mungbeans can be successfully cropped after maize harvest. Mungbean yields were low and ranged (0.07 to 0.80 t/ha) depending on location. Whilst using pre-plant herbicide did not necessarily increase yield, it did decrease labour costs, and therefore tended to increase net profit and return on labour.

Theme 3 is assessing opportunities for diversifying agricultural production, particularly through sandalwood systems. Two approaches (remote sensing and ground-truthing census data) for estimating sandalwood tree numbers for a national inventory were considered in 2024, however remote sensing methods proved to be challenging due to the semi-deciduous nature of the trees.

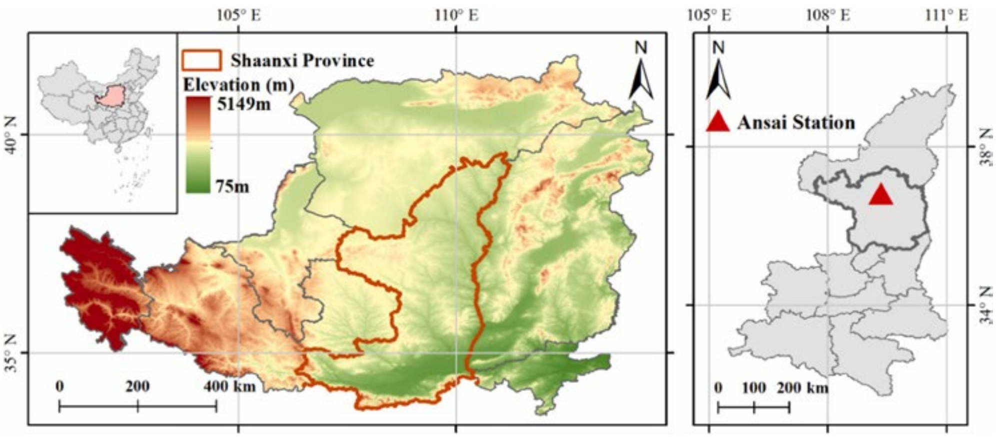
Theme 4 explores the benefits of improved knowledge of soils, intensification, and diversification for women in agriculture. Focus group discussion were held with female and male farmers in 2024, and aimed to assess changes in weed management and crop selection in specific regions of Timor-Leste. Preliminary findings show the inclusion of herbicides has increased farm income received, and for a broad range of crops.

The project is ongoing, and will continue to work alongside Timor-Leste's researchers and farmers to scale up agricultural technologies, aiming to enhance agricultural production in Timor-Leste and improve the livelihoods of rural households.

This research is supported ACIAR and UWA.

Luis Pereira, in-country Technical Country, inspecting conservation agriculture experiments with colleagues and local farmers.

Biochar addition mitigates asymmetric competition of water and increases yield advantages of maize-alfalfa strip intercropping systems in a semiarid region on the Loess Plateau



Geographic location of the study site.

Project team: Professor Peizhi Yang[2] (Project leader, yangpeizhi@126.com), Zhixin Zhang[2], Luanzi Sun[2], Shuai Hou[2], Xingrong Sun[2], Guohao Chen[2], Hackett Professor Kadambot H.M. Siddique[1], Zelin Chen[2], Fu Liu[2], Shiyu Ping[2], Hongtao Lai[2], Hongheng Guo[2], Yajing An[2], Zhiling Lin[2].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China.

Water scarcity in semiarid regions limits crop productivity, particularly in intercropping systems where competition for water can be intense. A two-year field trial in the Loess Plateau examined the role of biochar in improving water use efficiency (WUE) and productivity in maize–alfalfa strip intercropping. The study compared monocropping (sole maize and sole alfalfa) and intercropping, with biochar applied either to both crops or solely to maize or alfalfa.

Intercropping increased yield by 11.4% compared to expectations, and biochar application further improved forage production and WUE across all systems. Applying biochar solely to alfalfa resulted in a higher land equivalent ratio and water equivalent ratio than applying it solely to maize. However, the greatest improvements were observed when biochar was applied to both intercropped maize and alfalfa, increasing yield by 16.1%–16.6% and WUE by 6.7%–10.3%, leading to a 24.9%–26.3% rise in economic benefits.

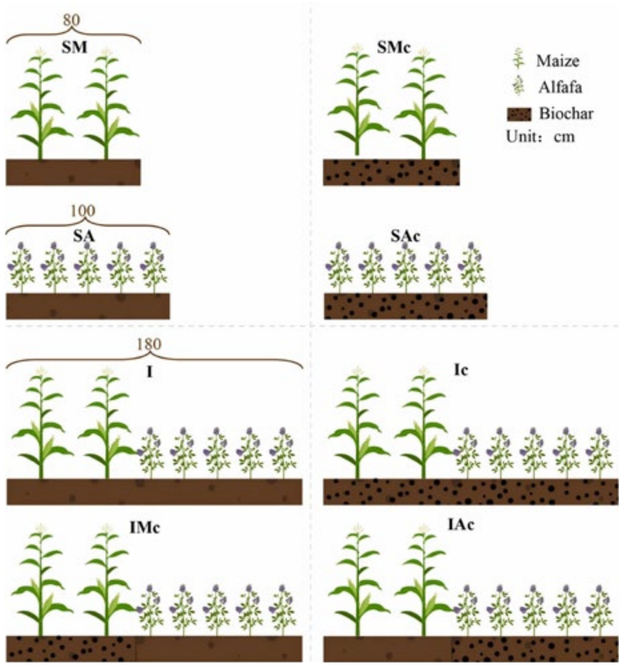


Diagram of different treatments for maize–alfalfa monoculture or intercropping systems.

Biochar enhanced soil water retention, promoted root growth, and reduced competition between crops, helping to mitigate water imbalance in intercropping systems. While these findings highlight biochar's potential in optimising intercropping systems, excessive soil water consumption remains a risk, emphasising the need for balanced water management strategies. This study provides valuable insights into sustainable water use in rainfed agriculture, particularly in dryland forage production.

This research is supported by the National Natural Science Foundation Youth Fund and the National Grassland Industry Technology System, Yulin Experimental Station.

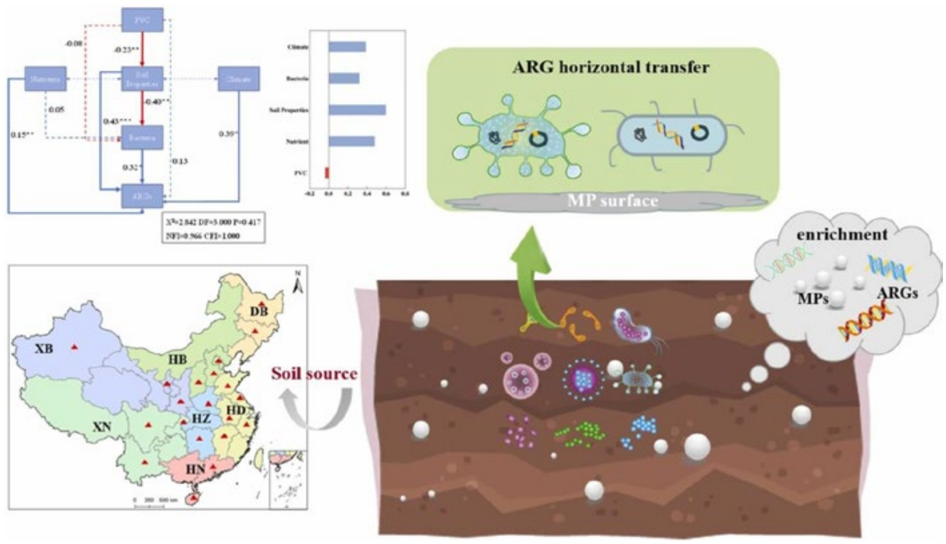
Polyvinyl chloride microplastics disseminate antibiotic resistance genes in Chinese soil: A metagenomic analysis

Project team: Professor Qianru Zhang[2] (Project leader, zhangqianru@caas.cn), Shuwen Zhao[2], Qilan Huang[2], Chuchen Zhang[2], Hongna Li[2], Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]Chinese Academy of Agricultural Sciences, China.

Microplastics (MPs) are pervasive environmental contaminants, with polyvinyl chloride (PVC) among the most commonly detected in soil. While research has explored the effects of MPs on microbial communities, their role in shaping antibiotic resistance gene (ARG) dynamics remains less understood. Given that soils serve as reservoirs for both MPs and ARGs, investigating these interactions is essential for assessing potential environmental and public health risks.

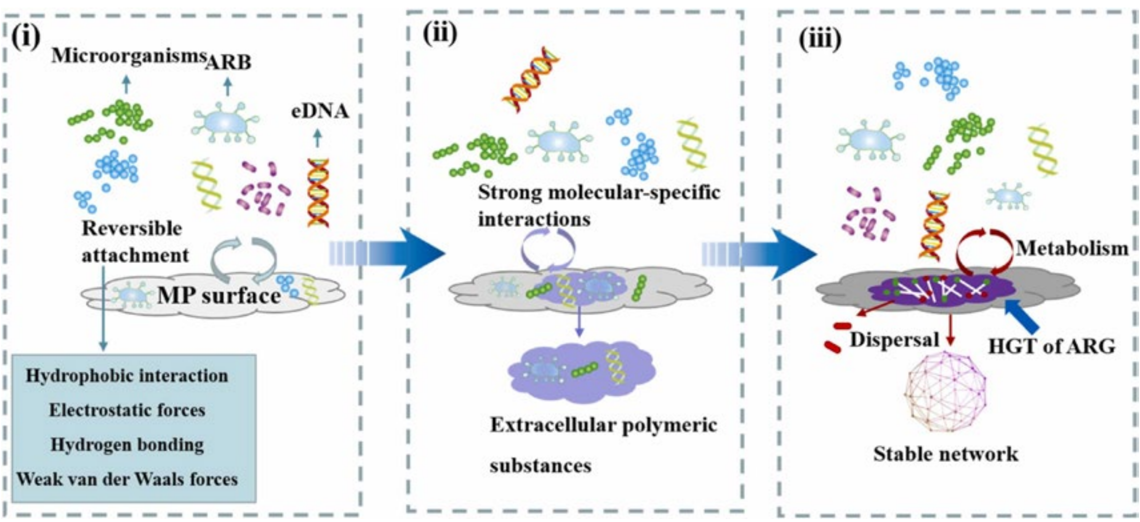
This study examines the effects of PVC MPs on soil bacterial communities and ARG abundance using soil samples from 20 provinces across China. Results indicate that PVC significantly alters microbial community structure and ARG distribution. Structural equation modeling suggests that these changes are mediated through modifications in soil properties, which in turn influence bacterial hosts of ARGs. Network co-occurrence analysis further reveals strong associations between bacterial community composition and ARG profiles, highlighting the role of MPs in shaping resistance gene dissemination.



Graphical Abstract.

Notably, soils from the HZ and HB regions in China exhibited the most pronounced shifts in bacterial and ARG diversity. The study underscores the complexity of MP interactions within soil ecosystems, particularly in influencing microbial composition and ARG abundance. Given the widespread occurrence of MPs, their potential to act as vectors for ARGs raises concerns regarding environmental antibiotic resistance. Future research should prioritise long-term field studies to assess the persistence and behavior of MPs across different soil types, as well as their impact on microbial gene transfer. Additionally, investigations into the degradation mechanisms of MPs and their influence on resistance development are necessary to inform sustainable plastic waste management strategies. Understanding these interactions is critical for mitigating the environmental spread of ARGs and reducing associated risks to human and ecosystem health.

This research is supported by the International Science & Technology Innovation Program CAAS, the National Natural Science Foundation of China, and the Young Scientist Exchange Program between the People's Republic of China and the Republic of Korea.



ARGs enrichment process and possible mechanism with the formation of MPs.

Changes in the proteome of florets associated with heat stress during the early reproductive stages in Brassica napus

Project team: Professor Wallace Cowling[1] (Project leader, wallace.cowling@uwa.edu.au), Dr Xiaoke Ping[2], Dr Sheng Chen[1], Xiaojie Hu[1], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]College of Agronomy and Biotechnology, Southwest University, China.

Heat stress significantly reduces oilseed rape grain production, especially heat stress that occurs during the early reproductive stages. Pollination, fertilisation and early embryo development are all highly sensitive to heat. This study explored changes in the proteome of florets of three *Brassica napus* cultivars that were exposed to transient heat stress during fertilisation and early embryo development. When the second flower on the main stem opened, the 2nd to 5th florets were hand-pollinated with healthy pollen and plants were moved to a control treatment (25 °C/15 °C) or a daily transient heat stress treatment (32 °C/22 °C) for seven days. Seed yield in pods on these florets was measured at maturity. The three cultivars, Alku, AV-Ruby, and YM11, exhibited varying degrees of heat sensitivity and heat resilience.

There were hundreds of differentially expressed proteins (DEPs) identified across the three cultivars and four time points. Among the DEPs, three proteins were consistently highly expressed under heat and were strong candidates as heat response proteins, which deserve further study for their potential involvement in heat tolerance.

This research is supported by China Scholarship Council, UWA International Fee Scholarship, GRDC, UWA IOA.

Initiation of heat treatment: marked by the opening of the second flower on the main stem.

Effects of heat stress on the main stem – the plant on the left was from the control treatment, and the plant on the right was exposed to 7 days of transient heat stress after the second flower opened on the main stem. Nearly all the flower nodes in the circled region failed to produce pods due to heat stress.

Project leader Tanushree Halder working in the wheat research field at the Sher-e-Bangla Agricultural University, Bangladesh.

Selection of wheat (*Triticum aestivum* L.) varieties under heat stress based on morpho-physiological, cytological and genetical characteristics

Project team: Associate Professor Tanushree Halder[1,3] (Project leader, halder.tanushree_gepb@sau.edu.bd), Professor Rakhahari Sarker[2], Professor Guijun Yan[1], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]University of Dhaka, Bangladesh; [3]Sher-e-Bangla Agricultural University, Bangladesh.

Wheat (*Triticum aestivum* L.) is the most important staple cereal in the world and ranks second position in Bangladesh. However, heat stress adversely affects wheat growth and development by disrupting water and nutrient uptake, impairing photosynthesis, reducing pollen viability, and affecting biochemical pathways, leading to reduced yield. Therefore, our research aims to select Bangladeshi wheat varieties based on their morpho-physiological, cytological, biochemical, and genetic traits under heat stress at the tillering and anthesis stages.

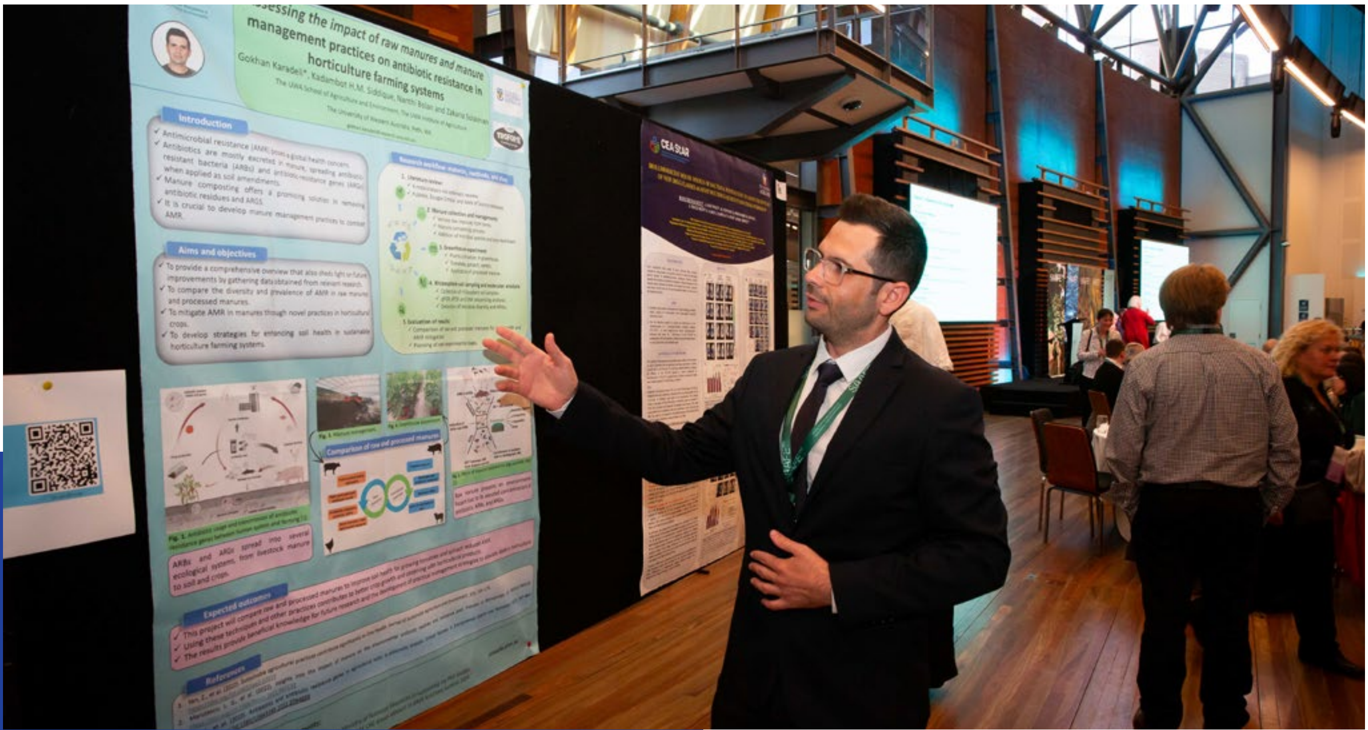
Four high-yielding Bangladeshi varieties and two pairs of near-isogenic lines (NILs), developed at UWA targeting the heat-tolerant genomic region (*QHtscc. ksu-7A*) (Lu et al., 2020), were used as plant materials. They were grown in field conditions with three different sowing dates—optimum, late, and very late. Agronomic traits, including rooting depth, number of nodal roots per plant, shoot height, tiller number, number of spikes per plant and grain yield per plant, of optimum and late sowing were evaluated. Additionally, number of pollens per spikelet was counted, and pollen viability and chlorophyll content and proline accumulation were measured. The data analyses are progressing. Higher proline accumulation was found in late transplanted genotypes than the optimum sowing; BARI Gom 33 had the highest proline accumulation at the tillering stage of all three sowings dates, indicating its potential for heat stress tolerance. However, further analyses are required for heat stress tolerant genotype selection.

Further, heat stress-associated genetic markers, including *Xbarc49* and *Xbarc121* of *QHtscc.ksu-7A*, will be used for marker analysis. Wheat varieties exhibiting higher morpho-physiological, biochemical, and cytological performance compared to NIL pairs under heat stress will be selected for future wheat stress breeding programs.

This research is supported by Sher-e-Bangla Agricultural Research System.

Funding bodies visiting the research field to investigate the research progress.

Unravelling the impact of manure management practices on antibiotic resistance and soil health in horticultural farming systems



PhD student Gokhan Karadeli presenting research findings.

Project team: Associate Professor Zakaria Solaiman[1] (Project leader, zakaria.solaiman@uwa.edu.au), Professor Nanthi Bolan[1], Gokhan Karadeli[1], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA.

Antimicrobial resistance (AMR) is a global problem that significantly burdens healthcare systems worldwide. A key contributor to this issue is the widespread use of veterinary antimicrobials for growth promotion and disease prevention in livestock farming. A considerable amount of these applied antibiotics is excreted in manure, leading to the dissemination of antibiotic-resistance genes (ARGs) and antibiotic-resistant bacteria (ARB) in horticulture after animal manures are used as soil amendments, making livestock manure a major environmental reservoir and transmission vector of AMR. Manure-borne ARGs can be taken up by horticultural crops often consumed raw and grown in untreated manure-amended soils, causing transfer from soil to humans through the food chain and exacerbating foodborne illnesses.

Manure composting is a promising solution for effectively removing antibiotic residues, ARB, and ARGs. While composting reduces the overall abundance of ARGs in manure, a considerable proportion can persist in the final compost. Therefore, developing novel manure management practices is crucial to tackling this challenge before direct soil application.

This project aims (i) to detect the prevalence and dissemination of ARB and ARGs in raw and processed manures, rhizosphere soils, and tissues of glasshouse-grown horticultural crops and (ii) to develop novel composting strategies to combat antibiotic resistance in livestock manure and horticultural farming systems.

AMR Research Group participated in the AMR Solutions Summit 2024, held in Adelaide, South Australia. At this summit, a poster presentation was presented, which included the background, main objectives and research plan for the project.

A systematic review and meta-analysis study on the presence of AMR in horticultural farming systems and crops was initiated to evaluate the distribution of data from the existing literature, as well as the spread, sources, and status of AMR in horticultural crops. The study is currently in the final stages of meta-analysis.

This project will provide economic and practical advantages in managing livestock manure and protecting food security in sustainable horticultural farming systems. Improved composting practices will help protect human health and welfare by reducing the AMR risk from animal manure in the One Health approach. This project will also offer key findings and insights for future research and development of manure management practices.

This research is supported by The Republic of Türkiye Ministry of National Education and UWA.

Unravelling the impact of rhizosheath size in wheat (*Triticum aestivum* L.) on drought and nutrient use efficiency

Project team: Pham Thi Thanh Huyen[1,2] (Project leader, huyen.pham@research.uwa.edu.au), Dr Jiayin Pang[1], Adjunct Professor Jairo Palta[1], Dr Sasha Jenkins[1], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]Thai Nguyen University of Agriculture and Forestry, Vietnam.

Rhizosheath—the soil layer that adheres to plant roots—plays a crucial role in plant resilience against environmental stresses like drought and aluminum toxicity. This protective sheath, formed through interactions between roots, soil, and microbes, is an adaptive trait that helps plants absorb water and nutrients more effectively. In Western Australia's Wheatbelt, a major grain-producing region, acidic soils dominate 75% of the landscape, creating significant challenges for wheat production.

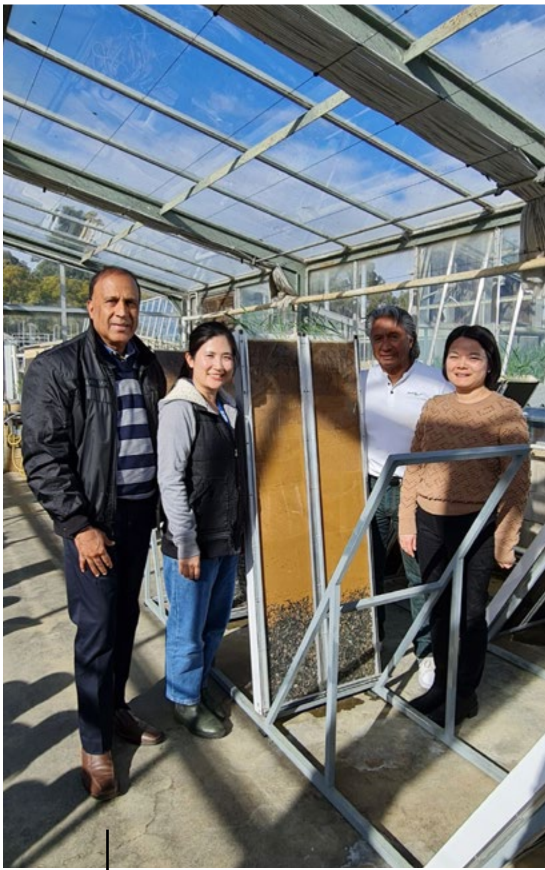
In her PhD research at UWA, Mrs. Huyen Pham examines five wheat lines with different rhizosheath sizes to understand how they handle drought and phosphorus deficiency in WA's acidic soils. Her study focuses particularly on wheat lines bred from a cross between Brazil's Fronteira cultivar (large rhizosheath) and Australia's Mace cultivar (small rhizosheath). The research aims to develop resilient, high-yielding wheat varieties that are better adapted to Western Australia's challenging growing conditions.

Her 2023 experiment revealed that Merredin's highly acidic, aluminum-rich soil affects rhizosheath development in different wheat lines. For the 2024 study, her team set up rhizobox and column experiments using actual field soil to replicate natural conditions and study root system characteristics. They monitor root growth through transparent panels for detailed analysis of root structure and plant performance, while a separate column experiment tracks plant phenology and yield factors.

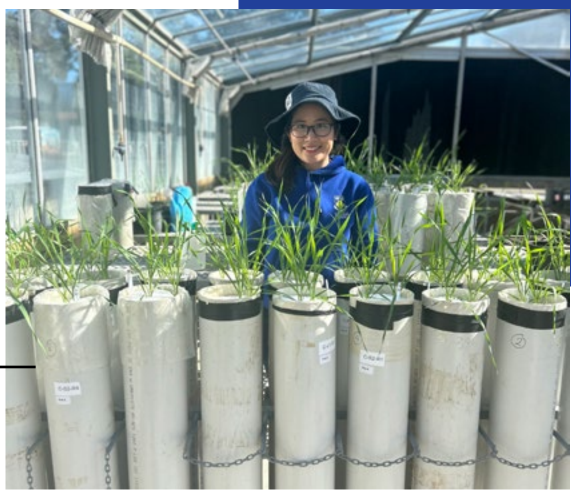
Initial results from Mrs. Pham's 2024 experiment reveal promising findings in root and shoot characteristics, plant performance, and yield components, while soil microbial analysis continues. The large rhizosheath wheat lines (L_1, L_3) showed exceptional adaptation to acid soils, with 33% larger root-to-shoot ratios and root volumes of 34-36 cm^3 per plant. Comparing rhizosheath dry weights, L_1 and L_3 demonstrated superior performance with approximately 31% greater mass than their smaller counterparts S_1 and S_2 (35.86g vs 27.37g). These varieties exhibited intelligent root distribution, concentrating 80% of growth in the less acidic topsoil layer. This adaptive strategy resulted in 15-29% higher grain yields and improved spike development compared to smaller rhizosheath varieties, though grain filling showed room for improvement. Building on these insights, Mrs. Pham will proceed with testing two wheat lines of contrasting rhizosheath sizes under early-season drought and low-phosphorus conditions.

This research highlights the potential of enhanced root traits to improve wheat adaptation to WA's acidic soils, contributing to the development of more resilient cropping systems.

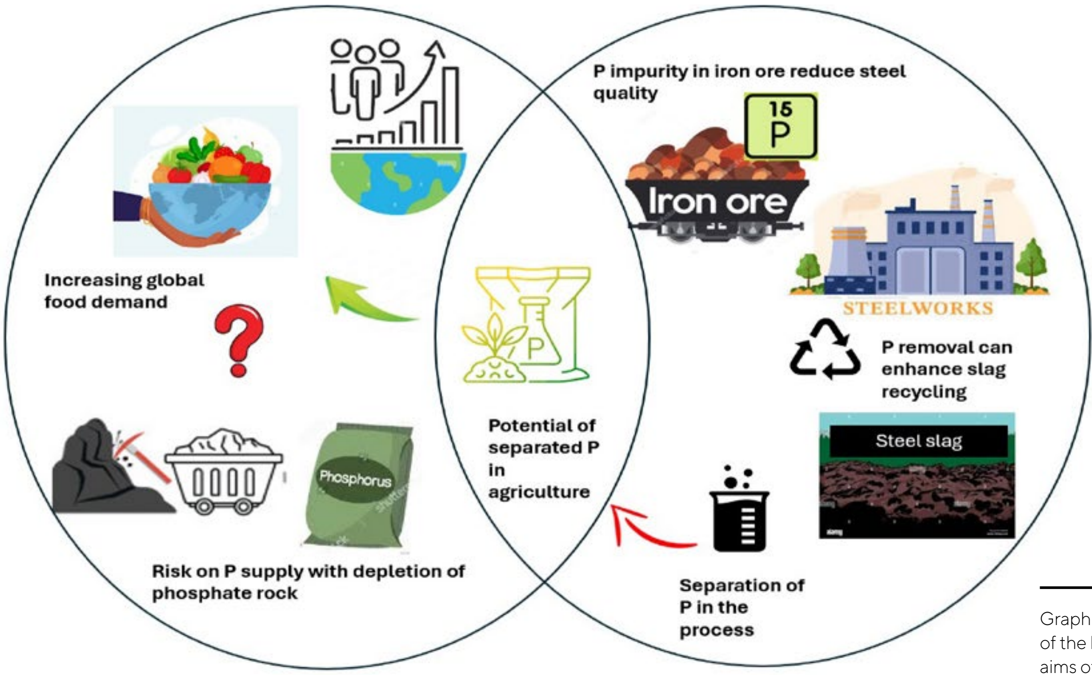
This research is supported by The Vietnamese Ministry of Education and Training, UWA IOA, WAARC and , SW WA Hub.



PhD student Mrs Huyen Pham and her research supervisor inspect the rhizobox experimental setup .



Mrs Huyen Pham with wheat column experiments.



Graphical representation of the background and aims of the project.

Innovative use of phosphorus-enriched steel slag for sustainable agriculture

Project team: Professor Nanthi Bolan[1] (Project leader, nanthi.bolan@uwa.edu.au), Mrs Ruwani Hapuarachchige[1], Hackett Professor Kadambot H.M. Siddique[1], Associate Professor Zakaria Solaiman[1], Dr James O'Connor[1].

Collaborating organisations: [1]UWA; University of Wollongong; University of Newcastle; BHP Innovation Pty Ltd.

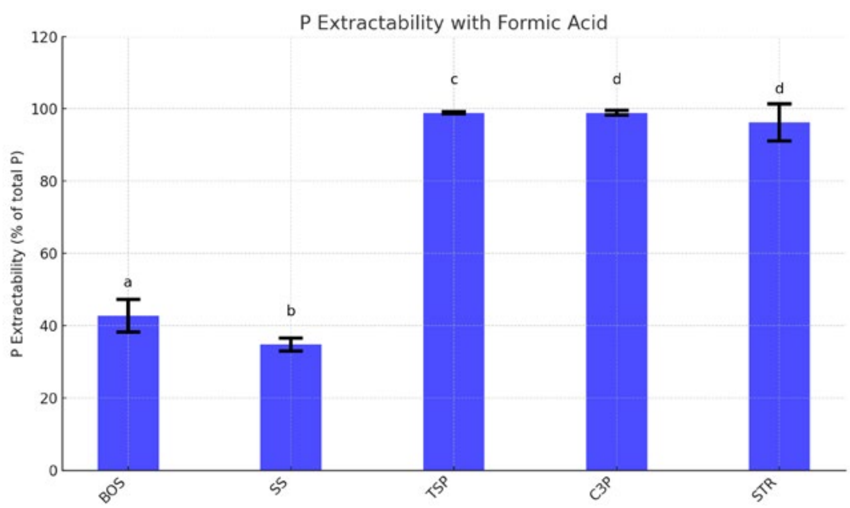
The finite nature of phosphate rock and the environmental challenges of conventional phosphate (P) fertilisers highlight the need for alternative P sources. Steel slag, a by-product of steel production, has emerged as a promising source for recycling into agriculture. Phosphorus reduces steel quality as an impurity in iron ore, and separation of P rich phase and Iron rich phase in the steel manufacturing process can improve recycling of slag in the steel production. This project focuses on a P-enriched co-product from steel slag, produced through a phase-segregation process, and compares its effectiveness as a P fertiliser with conventional P fertilisers across various soil types.

In the year 2024, the experimental progress included a preliminary study evaluating Basic Oxygen Furnace Slag and a lab-synthesised Synthetic Slag for their chemical composition. In addition, the solubility of these materials was compared with Tri-calcium Phosphate, Struvite, and Triple Superphosphate (TSP) using two extraction methods: Neutral Ammonium Citrate and 2% Formic Acid.

Although the total P content of steel slag products was significantly less than TSP, the findings highlight the promise of reusing steel slag materials for sustainable P management. The findings will be linked to the next experiments with soil to understand the P dissolution of the steel slag co-products in different soils and to investigate the growth response of the wheat crop for different P rates of the steel slag co-products compared to TSP fertiliser in 2025.

The project aims to identifying key knowledge gaps, to support future research and the development of sustainable practices that influence the application of steel slag co-products for enhanced soil health and productivity in agriculture particularly as a P fertiliser.

This research is supported by ARC Linkage Project funding, BHP Innovation PTY LTD and GRS (UWA).



Extractability of P in different samples with 2% formic acid. A Tukey's post-hoc test was conducted to compare P extractability among BOFS, SS, TSP, C3P, and STR under Formic Acid extraction. Groups with different letters are significantly different ($p < 0.05$).

Root-exudates-microbiome cascading interactions enhancing soybean growth and phosphorus acquisition in cultivar mixtures with complementary phosphorus-acquisition strategies

Project team: Professor Wen-Feng Cong[2] (Project leader, Wenfeng.cong@cau.edu.cn), Boyu Zheng[1], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]China Agricultural University, China.

Soybean is a vital crop for global food security, yet its productivity is often constrained by phosphorus (P) availability. Given the environmental and economic costs of P fertilisers, improving P acquisition efficiency in soybean is crucial for sustainable agriculture. This project investigates how cascading root–exudates–microbiome interactions in soybean cultivar mixtures enhance growth and P uptake, contributing to a deeper understanding of belowground facilitation mechanisms.

The key research objectives are: (1) to determine whether neighboring plants in cultivar mixtures drive microbial-rhizosphere-root interactions that improve P acquisition, (2) to identify specific metabolites secreted by soybean cultivars that mediate these interactions, and (3) to assess the role of enriched rhizosphere microbial taxa in enhancing soybean growth and P uptake.

Progress has been made in 2024. Greenhouse experiments have been conducted, revealing facilitation effects in specific cultivar combinations, particularly in BC mixture treatments. Data collection has included root trait measurements and biomass assessment. Further analyses such as untargeted metabolomics, microbial community profiling (16S, ITS sequencing), and network co-occurrence modeling are planned to elucidate the complex belowground interactions. The preliminary findings support the hypothesis that cultivar mixtures with complementary P acquisition strategies can enhance biomass.

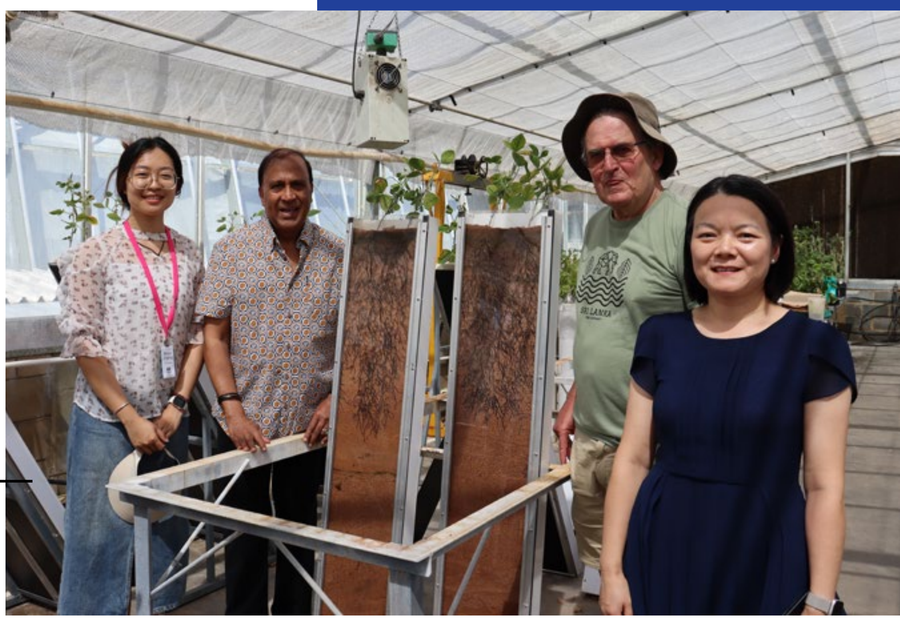
This research has the potential to inform breeding programs and agronomic strategies aimed at optimizing root traits and microbial interactions for improved P use efficiency. By identifying effective cultivar combinations and their associated microbiome shifts, this project contributes to the development of more sustainable soybean production systems with reduced reliance on synthetic P fertilisers.

The findings will help advance knowledge in plant-soil-microbe interactions, offering practical solutions for enhancing agricultural sustainability.

This research is supported by CSC, ARC and NNSFC.

Rhizobox experiment: greenhouse setup for investigating root interactions in soybean cultivar mixtures.

Soybean in the glasshouse experiment.



PhD student Boyu Zheng in the glass house with supervisors.

Uncovering above- and below-ground microbiome dynamics in the *Leptosphaeria maculans-Brassica napus* pathosystem

Project team: Professor Jacqueline Batley[1] (Project leader, jacqueline.batley@uwa.edu.au), Maria Lee[1], Dr Angela van De Wouw[2], Dr Aria Dolatabadian[1].

Collaborating organisations: [1]UWA; [2]University of Melbourne.

Blackleg disease caused by the fungus Leptosphaeria maculans is a major threat to canola (Brassica napus) production. Canola blackleg disease management involves agricultural practices such as crop rotations and stubble removals, chemical application, and plant resistance genes deployment. However, resistance breakdown and fungicide tolerance are unavoidable due to the ability of the pathogen to mutate rapidly.

While swift progress has been made in deploying disease resistance genes, information on the protective function of the microbial population against plant pathogens in the monoculture model cash crop B. napus has remained understudied. There is limited information on how resistance genes and abiotic factors may structure pathogenic or beneficial members of the plant host microbiota in the L. maculans – B. napus pathosystem.

Little is known about the microbial landscape within the plant compartments and soil surrounding the root networks during healthy plant host development compared to its infected counterparts. Microbiome profiles will provide valuable knowledge to current integrated trifecta canola blackleg disease management. In addition, microbiome functions in agroecosystems offer immense potential in predicting disease outbreak models with critical signature species and guild species that may enhance resistance against L. maculans.

This study aims to investigate microbiota composition in different canola cultivars and plant compartments involving experimental setups in the glasshouse. Microbiota recruitments will also be characterised during stages of plant host development with and without L. maculans through plot land. Further field sampling will help to close the gaps in understanding how abiotic factors and anthropogenic activities can shape root-associated microbiomes in the Australian canola field. Microbial abundance and composition of bacteria and fungi with keystone species will be analysed via metagenomics and bioinformatics.

Figure 1: Glasshouse microbiome experiment setup.

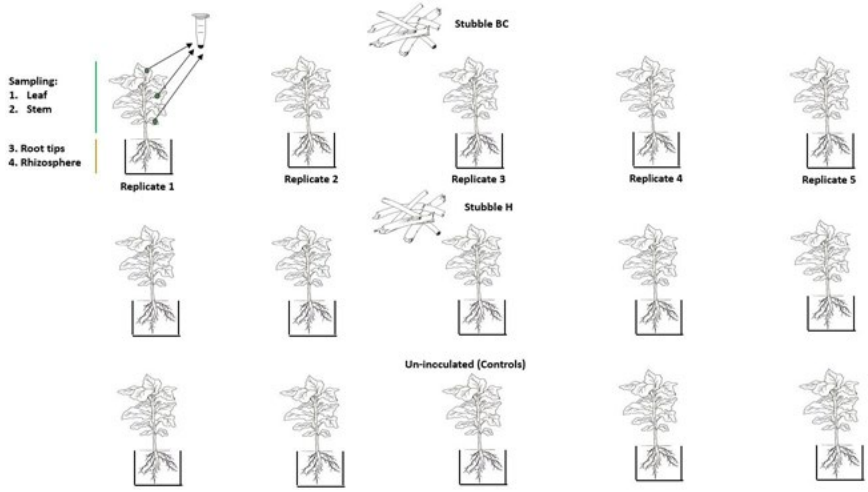


Figure 2: a) Seeds were sown in replicates for all six selected canola cultivars. b) Stubble inoculation method to infect canola plants. c) Multiple pseudothecia of *L. maculans* (red circle) forming on the stubbles used to inoculate the canola plants. d) The humidity chamber with a tarp cover to promote ascospores release from the stubbles.

In collaboration with Dr Angela van De Wouw, the glasshouse experiment was conducted in Horsham, Victoria. Canola cultivars with different resistance characteristics, from susceptible to moderate to highly resistant varieties, were exposed to two different stubbles from paddocks with different cultivars growing (Fig. 1). Stubbles were collected from the field and previously characterised with the ability to infect specific canola populations. A third set of replicates was set aside as un-inoculated controls. Plant tissues and soil samples from the rhizosphere were collected in triplicate from different sites within individual plants (Fig. 2).

DNA extractions, optimization of amplification with selected primer sets targeting 16S/18S rRNA, next-generation sequencing, and data analysis will be completed during the first half of 2025. The outcome of this study will provide a better understanding of microbiota composition in different plant compartments between various canola cultivars in healthy and blackleg-infected plants in a controlled glasshouse environment. It offers a potential to identify beneficial members of the microbiota with antagonistic properties against L. maculans.

Part of the long-term research goal is to improve canola production through alternative and sustainable approaches in addition to the currently utilised trifecta management of canola blackleg disease.

This research is supported by UWA.

Exploring the mechanisms underlying the regulation of seed Phosphorus filling and phytate metabolism in chickpea

Project team: Dr Jiayin Pang[1] (Project leader, jiayin.pang@uwa.edu.au) Huaikang Jing[1], Emeritus Professor Hans Lambers[1], Hackett Professor Kadambot H.M. Siddique[1], Associate Professor Peta Clode[1].

Collaborating organisations: [1]UWA.

Phosphorus (P) is an essential macronutrient for plant growth and an important structural component of nucleic acids, proteins and plasma membranes. With over 60% of aboveground P allocated to seeds, grain P removal plays a critical role in the global P cycle. Reducing seed P concentration offers a promising strategy to minimize P export and lower fertiliser demand, contributing to more sustainable agricultural practices.

Phytic acid (myo-inositol-1,2,3,4,5,6-hexakisphospate) is the storage form of P in seeds, typically representing from 75 ± 10% of seed total P. Following synthesis during seed development, it accumulates and is deposited as mixed phytate of various mineral cations primarily of potassium (K), magnesium (Mg), calcium (Ca), manganese (Mn), zinc (Zn), and iron (Fe), thereby reducing their bioavailability and causing micronutrient deficiencies in humans or animal. Therefore, improving the P-use efficiency of crops is pivotal to promote the sustainable production of global agriculture, and reducing seed phosphorus and phytate content represents a key strategy to address this challenge. However, limited progress has been made in elucidating the mechanisms underlying seed P filling in legumes represented by chickpeas.

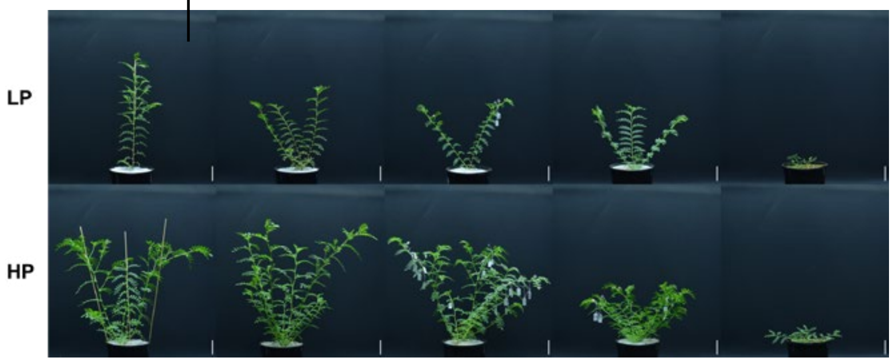
Chickpea (*Cicer arietinum* L.) is a diploid strictly self-pollinating and the third most cultivated legume crop globally. To investigate how differences in phytate and P concentrations in chickpea seeds are influenced by genetic factors, environmental factors and their interactions, five chickpea genotypes differing seed P concentrations (three with high seed P and two with low seed P) were grown under two P levels (20, 60 mg·kg^{-1}). Considering the three key phases of nutrient accumulation in developing seeds—cell division immediately after pollination, cell expansion following division, and the subsequent storage phase—time-course experiments were conducted to investigate the dynamic changes in seed phosphorus and phytate concentrations throughout development. The study aimed to explore the regulatory mechanisms underlying seed P and phytate concentrations in chickpea.

The specific objectives of this study are:

i) Investigate how different P supply levels affect phytate concentrations in chickpea genotypes and assess the interactions between environmental and genetic factors.
ii) Examine dynamic changes in phytate and P concentrations at different stages of seed development.
iii) Explore dynamic correlations between seed phytate concentrations and the bioavailability of metal elements.
iv) Investigate how mineral elements affect phytate metabolism using Cryo-FESEM-EDS to quantitatively visualise the cellular elemental distribution of chickpea seeds at different developmental stages.

This research is supported by UWA, ARC Linkage Project, Guangzhou Debai AgroTech, Yingkou Magnesite Chemical Ind Group, and China Agricultural University.

Growth performance of five chickpea genotypes under low-phosphorus (LP) and high-phosphorus (HP) conditions.



Chickpea seeds harvested at different developmental stages.

Exploring phosphorus resorption efficiency in chickpeas

Project team: Hackett Professor Kadambot H.M. Siddique[1] (Project leader, kadambot.siddique@uwa.edu.au), Mr Xiaolong Feng[1], Dr Jiayin Pang[1], Emeritus Professor Hans Lambers[1], Associate Professor Peta Clode[1].

Collaborating organisations: [1]UWA.

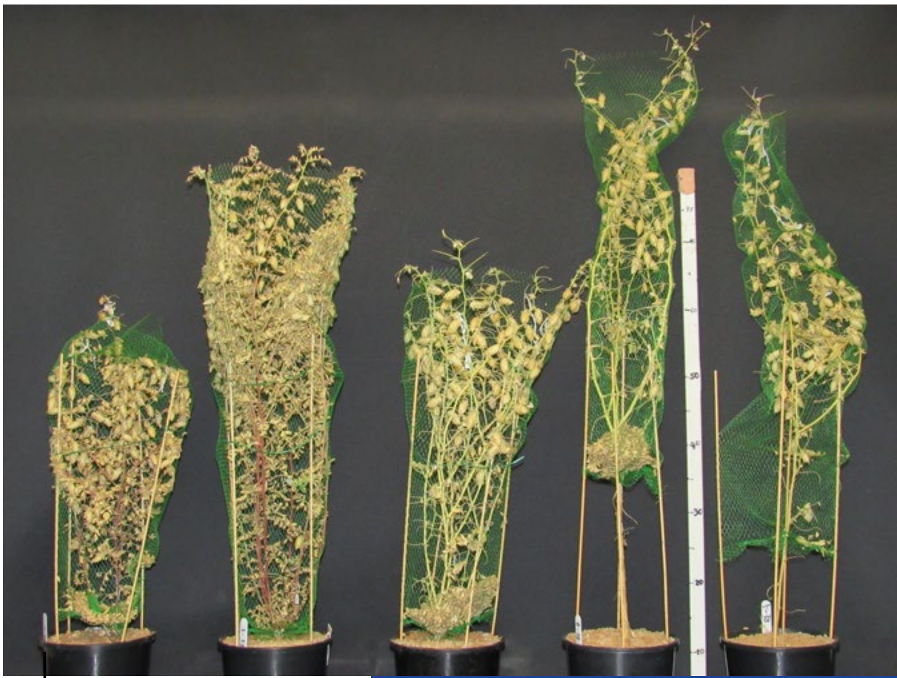
While we understand that P resorption is crucial for productivity per unit P uptake (PUE), studies on the physiological and metabolic factors contributing to differences in P resorption are limited. Historically, more emphasis has been placed on improving the acquisition of P from the soil, overlooking the role of P resorption in PUE, hindering further efforts to screen and breed high-PUE crops. Given the increasing scarcity of rock phosphate, the primary raw material for phosphate fertiliser production, increasing the remobilisation of acquired P within plants to support the growth of newly developed vegetative or reproductive organs becomes critical in reducing the dependence on phosphate fertilisers. Therefore, uncovering the underlying causes of differences in PRE is of utmost importance.

This project will focus on chickpea, the third most widely cultivated legume globally, especially in regions with marginal soils and semi-arid conditions. The urgency of breeding efficient chickpea genotypes for P utilisation is increasing due to P deficiency constraints. Our previous experiment investigated the difference in PRE among 266 genotypes, and we selected two high- and three low-PRE genotypes to uncover the underlying mechanisms encoding PRE. The following hypotheses will be tested:

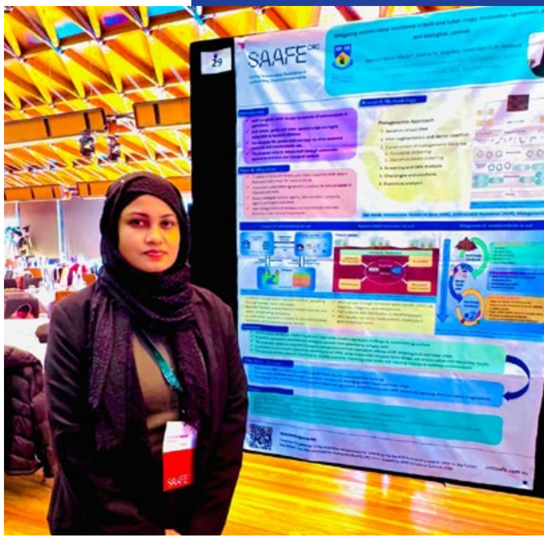
1) During leaf senescence, P in mesophyll cells is preferentially recycled with the extent of P resorption from epidermal cells determining variation in PRE.
2) Genotypes with a greater resorption of lipid P will have a higher PRE.
3) The ability of stem P storage mediates PRE, and genotypes with low stem P storage have higher requirements for resorption.
4) There is a consistent pattern of P resorption in leaves, stems and roots, and genotypes with higher leaf P resorption also have higher stem and root resorption.

This research is supported by the CSC, UWA top-up scholarship and ARC.

Reproductive period of five chickpea accessions with different phosphorus resorption efficiency.



Mature harvest period of five chickpea accessions with different phosphorus resorption efficiency.



PhD student Kamrun Nahar Sheuly presenting the research at the CRC SAAFE 2024 Conference.

Mitigating antimicrobial resistance in bulb and tuber crops: innovative agronomic practices and biological controls

Project team: Hackett Professor Kadambot H.M. Siddique[1] (Project leader, kadambot.siddique@uwa.edu.au), Associate Porfessor Zakaria Solaiman[1], Professor Nanthi Bolan[1], Kamrun Nahar Sheuly[1].

Collaborating organisations: [1]UWA.

Antimicrobial resistance (AMR) poses an increasing risk to global food security and agricultural sustainability. In bulb and tuber crops, such as onions and potatoes, the misuse and overuse of chemical controls have intensified the emergence of resistant bacterial pathogens, jeopardizing productivity and crop health. This project explores alternative, sustainable strategies to mitigate AMR in key bacterial diseases affecting these crops. By integrating molecular biotechnology, biological control agents, and tailored agronomic practices, the project aims to lessen reliance on traditional antimicrobials and improve crop resilience.

The overarching goal of this project is to devise and implement innovative strategies to mitigate AMR in bulb and tuber crops through sustainable agronomic practices and biological controls. The specific aim are 1. Conduct a thorough literature review and gather baseline data on the incidence of AMR in bulb and tuber crops for meta-analysis. 2. Develop and implement sustainable agronomic practices to minimize bacterial diseases and AMR in bulb and tuber crops. 3. Evaluate the effectiveness of biological control agents, including microbial consortia, in managing pathogenic bacteria and AMR. 4. Utilize metagenomic approaches to analyse the composition of the soil microbiome and the diversity of antimicrobial resistance genes (ARGs) under various agronomic and biological control treatments.

Compared to livestock and broadacre systems, research on AMR in bulb and tuber crops is limited. Sustainable alternatives such as biochar and microbial consortia are still underexplored for AMR mitigation. The role of biological control agents in the rhizosphere is poorly defined, and few studies correlate soil health parameters with AMR gene prevalence. Furthermore, the application of metagenomic tools to evaluate the impact of agronomic practices on soil AMR is still nascent.

A comprehensive literature review has identified significant findings and research gaps concerning AMR in crop systems. Baseline soil samples have been collected from peri-urban plots for AMR and microbiome analysis. Soil physico-chemical assessments are ongoing, and DNA extraction protocols have been established for 16S rRNA sequencing and qPCR.

The research team participated in the CRC SAAFE summit in Adelaide, South Australia to connect with industry and academic stakeholders. A poster based on the project has also been accepted for presentation at an international research conference scheduled for September 2024.

This research will produce critical knowledge and practical tools to mitigate AMR risks in Australian bulb and tuber cropping systems. By integrating metagenomics, sustainable agronomy, and biological controls, the project fosters long-term biosecurity, enhances soil and plant health, and reduces dependence on chemical antimicrobials—supporting Australia's sustainable agriculture and food safety objectives.

This research is supported by UWA.

Collecting rhizosphere soil samples from a peri-urban farm.

Elucidating genes against blackleg in *Brassica napus* germplasm

Project team: Professor Jacqueline Batley[1] (Project leader, jacqueline.batley@uwa.edu.au), Hackett Professor Kadambot H.M. Siddique[1], Dr Angela Van de Wouw[2], Dr Junrey Amas[1], Dr William Thomas[1], Dr Aria Dolatabadian[1].

Collaborating organisations: [1]UWA; [2]University of Melbourne; Marcroft Grains Pathology.

Brassica spp., also known as *Brassica* vegetables or cruciferous crops, are a group of plant species essential for human nutrition and agriculture. This group includes canola (*Brassica napus*), a globally important source of highly nutritious vegetable oil. Canola plays an important role in Australia's oil industry, but its production is impacted by diseases such as blackleg, caused by the fungal pathogen *Leptosphaeria maculans*. Understanding the disease resistance mechanisms in canola can lead to the development of effective strategies for disease management and crop improvement, benefiting agriculture.

This project employs multiple DNA-sequencing technologies to identify genes that confer resistance to blackleg disease in canola. These technologies include short-read amplicon sequencing, SNP-chip genotyping, and high-fidelity long-read sequencing. Standard and high-molecular-weight DNA extraction, PCR analyses, and SNP-chip genotyping were conducted at UWA, while phenotyping for blackleg disease was performed in Horsham, Victoria, in collaboration with Dr Van de Wouw from the University of Melbourne.

Highlights of this research include:

- GWAS: Phenotypic and genotypic data were used to conduct preliminary genome-wide association studies (GWAS) using a 90K SNP-chip with *Rlm1*-segregants. The observed phenotype displayed a clear bimodal distribution, confirming a major gene as the source of resistance. The results showed that the chromosome A07 (10) has the highest number of markers, most likely associated with the *Rlm1* gene. Mapping the three SNPs with the location in the Darmor v10 reference genome will help narrow down the candidate gene from the list in RGAugury of *Rlm1*-candidate genes.
- Candidate Gene Analysis: Primers were designed and tested for sequence variation between known resistant and susceptible lines to identify *Rlm1*-candidate genes. The results narrowed the region of interest to strong candidate genes based on the GWAS findings.
- Long-read Sequencing: three canola samples were initially sent for long-read sequencing with two known resistant and one susceptible entry. The results are still being analysed and would validate the results of the GWAS and candidate gene analyses. Identifying the *Rlm1* gene is important for the canola industry in Australia and globally.

The results from this study could be used as the basis for identifying other blackleg resistance genes. Ultimately, this could lead to the development of resistant canola varieties and towards a sustainable canola cropping system.

This research is supported by GRDC and DOST-SEI Foreign Scholarship Grant.

Mass inoculation of segregating canola lines with *L. malculans-AvRlm1* isolate using the spraying method at Horsham, Victoria.

Harvesting of canola pods in the glasshouse from population advancement BC1F2 between susceptible and resistant varieties.

PhD student Oshadi Hettithanthrige Dona extracting samples to assess the impact of humate on lime dissolution in soil.

Novel humate-based calcium formulations to ameliorate subsoil acidity, and to enhance soil health and crop productivity

Project team: Professor Nanthi Bolan[1] (Project leader, nanthi.bolan@uwa.edu.au), Hackett Professor Kadambot H.M. Siddique[1], Oshadi Hettithanthrige Dona[1], Associate Professor Zakaria Solaiman[1], Andrew Doecke[2].

Collaborating organisations: [1]UWA; [2]Omnia Specialities Australia Pty Ltd.

Subsoil acidification poses a significant threat worldwide, limiting crop yields. In Australia alone, approximately 24 million hectares (Mha) of soils face subsoil acidity challenges characterised by low pH levels, diminished basic nutrient cations like calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^{+}), and elevated concentrations of toxic acid cations such as aluminium (Al^{3+}) and manganese (Mn^{2+}).

Recent research suggests that an imbalance between cation and anion uptake by plant roots exacerbates this issue. Traditional surface lime applications are ineffective in addressing subsurface soil acidity due to the extremely slow movement of lime-derived alkalinity to deeper soil layers to neutralize subsoil acidity. However, combining lime with gypsum has shown greater efficacy in alleviating Al^{3+} toxicity and increasing pH than conventional liming practices.

Despite its initial effectiveness in managing subsoil Al^{3+} toxicity, long-term sustainability is hindered due to sulfate leaching from the gypsum. Alternative strategies like excessive lime broadcasting or deep ripping with lime placement, are costly and often impractical. Moreover, excessive lime application can induce other soil and nutrient constraints, including lime-induced iron and zinc deficiencies, ammonia volatilisation and phosphate immobilisation as in the case of calcareous soils.

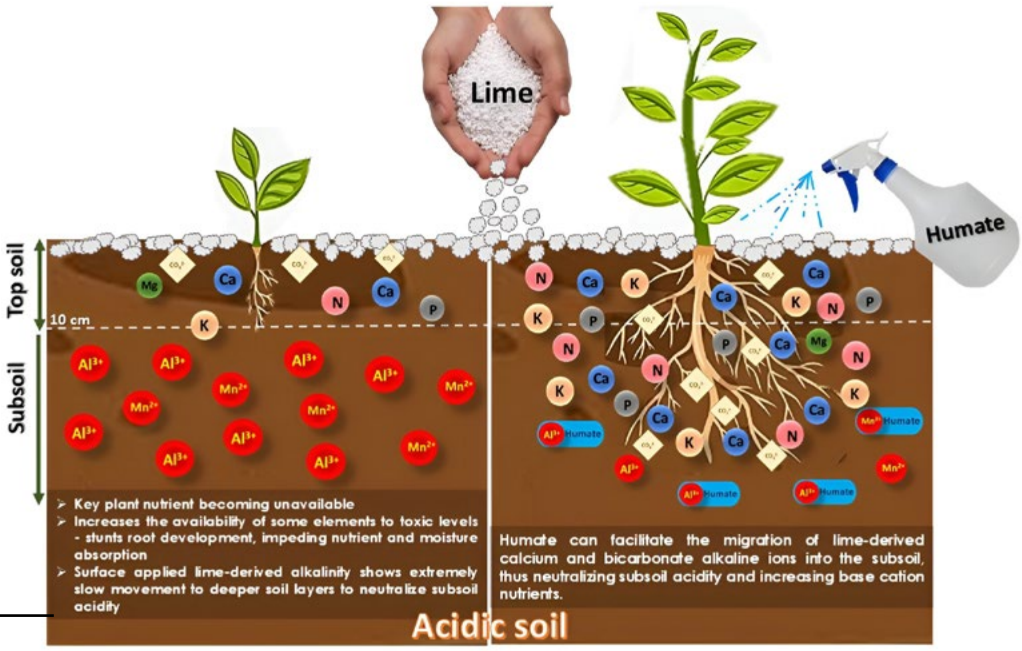
One promising approach to address subsoil acidity involves enhancing the mobility of liming materials to the subsoil by increasing their solubility and reducing their particle size, thereby promoting their colloidal movement. Amendments containing soluble constituents with greater mobility into the subsoil zone have shown promise in alleviating subsoil acidity when applied to the surface. Humic substances, like fulvic and humic acids, possess diverse range of functional groups—including carboxyl, amino, and hydroxyl groups—can facilitate the migration of lime-derived calcium and bicarbonate alkaline ions into the subsoil, thus neutralizing subsoil acidity and increasing base cation nutrients.

This study aims to ameliorate subsoil acidity through the surface application of humate based calcium formulation products. The innovative aspect of this study lies in addressing subsoil acidity by surface-applied liming materials combined with humic substances, thus circumventing the energy-intensive placement of liming materials in the subsoil zone.

The initial experiments showed that selected humate products are not retained by soil and therefore do not inhibit their effect on lime dissolution, and movement of calcium and bicarbonate alkaline ions into the subsoil. Furthermore, the soil functioned as a sink for dissolved ions, enhancing lime dissolution over time.

Future research will focus on comprehensive evaluation of the efficacy of humate-based lime formulations in improving soil properties, enhancing plant-available soil nutrients, reducing soil Al^{3+} toxicity, and promoting crop productivity.

This research is supported by Omnia Specialities Australia Pty Ltd and UWA.



The graphical abstract for the study.

Identification and functional validation of resistance genes in *Brassica napus L.* providing resistance against *Leptosphaeria maculans* infection through transient gene expression system

Project team: Professor Jacqueline Batley[1] (Project leader, jacqueline.batley@uwa.edu.au), Dr Angela Van De Wouw[2], Dr Maria Pazos Navarro[1], Dr Aria Dolatabadian[1], Dr Junrey Amas[1], Dr William Thomas[1], Zuhra Qayyum[1], Huma Qamar[1], Amanda Hewa Maithreege[1].

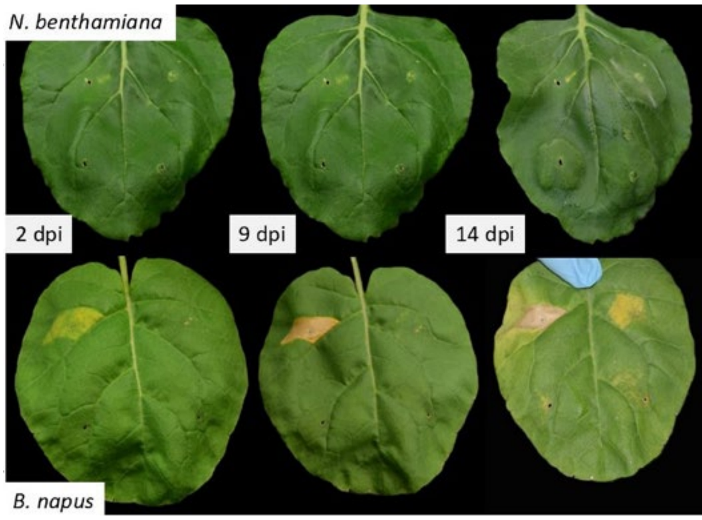
Collaborating organisations: [1]UWA; [2]University of Melbourne.

Canola (*Brassica napus*) is an important oilseed crop globally, playing a significant role in vegetable oil production. However, blackleg disease caused by the hemibiotrophic fungal pathogen *Leptosphaeria maculans* poses a serious threat to canola cultivation. In regions such as Australia, blackleg disease results in 10-15% annual yield losses, underscoring the importance of developing disease-resistant canola varieties.

Genetic control remains one of the most effective methods for managing blackleg disease in *B. napus*. Qualitative resistance follows a gene-for-gene interaction model, in which a plant's resistance (*R*) gene interacts with a corresponding avirulence (*Avr*) gene in the pathogen. This interaction triggers a hypersensitive response (HR) in the plant, leading to localised cell death that restricts pathogen spread. Quantitative resistance, on the other hand, involves multiple genes that contribute to partial resistance, often conferring durability under field conditions.

While several *R* genes have been identified as key contributors to resistance against *L. maculans*, validating a broader range of *R* genes in *B. napus* is essential for developing a more comprehensive and sustainable approach to disease management. The project aims to establish a transient gene expression system in *B. napus* and *Nicotiana benthamiana* for faster *R* gene identification and functional validation. The candidate *R* gene will be transiently expressed in *B. napus* and *N. benthamiana* plants through *Agrobacterium*-mediated infiltration. Following gene expression, the plants will be treated with fungal inoculum from *L. maculans* to induce a potential HR.

Nicotiana benthamiana and Brassica napus plants in a controlled environmental room.



Leaves of N. benthamiana and B. napus agroinfiltrated with candidate R genes to record the phenotypic HR.

In addition to phenotypic analysis, quantitative real-time reverse-transcription polymerase chain reaction (qRT-PCR) will be employed to measure gene activity within the plants, providing a more detailed understanding of the plant's response at the molecular level. The candidate *R* gene is tagged with green fluorescent protein to confirm the expression of the gene through fluorescence assay. We have achieved the transient expression of candidate *R* genes in the plant. The fluorescence microscopy confirms the expression of these genes with some expected phenotypic changes. We are further optimising the protocol with extended gene expression necessary for more robust HR detection.

A well-established transient expression protocol enables rapid introduction and expression of candidate genes in *B. napus* plants, providing a streamlined method for assessing gene function and identifying promising candidates for breeding. By significantly reducing the time required for gene validation, this system facilitates high-throughput screening and offers critical insights into the molecular mechanisms underlying resistance.

This research is supported by GRDC.

Enhancing nitrogen nutrient delivery for sustainable crop production

Project team: Professor Nanthi Bolan[1] (Project leader, nanthi.bolan@uwa.edu.au), Mr Manika Rani Debnath[1], Hackett Professor Kadambot H.M. Siddique[1], Associate Professor Zakaria Solaiman[1].

Collaborating organisations: [1]UWA.

PhD student Manika Rani Debnath adding acid to trap ammonia from her laboratory soil incubation experiment.

Visit of Prof. Bolan and Assoc. Prof. Solaiman to the Wheat and Canola experiment on ammonia volatilization and biomass production by CRNFs.

Nitrogen (N) use efficiency (NUE) in Australian agriculture remains suboptimal, particularly in arable crops and pastures, due to various soil and environmental factors. Water availability plays a crucial role in nutrient use and crop growth, directly influencing NUE. Given the increasing challenges of water scarcity and nutrient losses, there is a need for innovative fertiliser solutions that enhance both nutrient retention and soil water-holding capacity.

Controlled-release nitrogen fertilisers (CRNFs) have been developed to improve NUE by regulating nitrogen availability to match plant uptake. However, most CRNFs currently available are based on petroleum-derived synthetic polymers, which are costly and pose environmental risks as emerging contaminants. Alternative materials such as natural zeolites have been explored for CRNF development, but their limited nitrogen-loading capacity remains a major drawback. This project will highlight the potential of natural clays as a sustainable alternative, given their proven ability to improve moisture retention and nutrient availability in soils.

This research aims to investigate the potential of natural clay-based fertilisers in enhancing NUE and soil moisture retention. The study focuses on evaluating the effectiveness of CRNFs in improving crop nutrient uptake while reducing nitrogen losses. By leveraging the beneficial properties of natural clays, the project seeks to develop a cost-effective and sustainable fertiliser solution tailored for Australian agricultural systems.

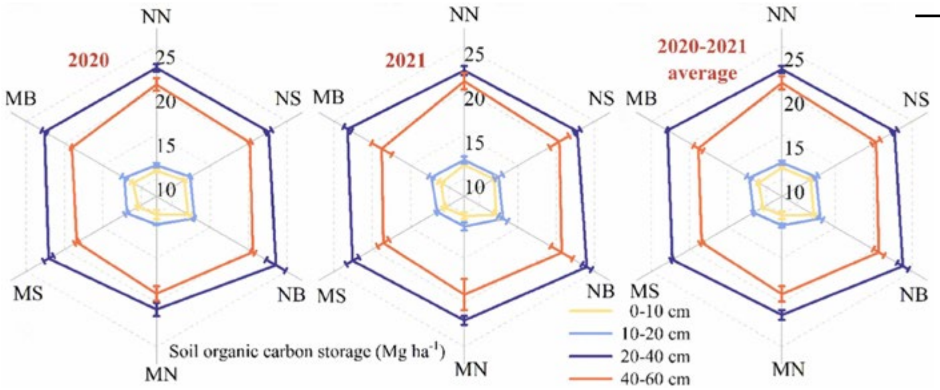
The main progress and highlights of the study in 2024 include:

- A comprehensive literature review on slow-release nitrogenous fertilisers, culminating in a meta-analysis on their impact on cereal crop grain production.
- Assessed of ammonia volatilization loss from traditional and coated urea N fertilisers in two soils, demonstrating less volatilization loss in clay-rich soil.
- Investigated the effects of traditional and coated urea on biomass production in wheat and canola, revealing significant differences in root biomass in canola between N fertiliser sources.
- Initiated a leaching experiment to assess nitrogen losses from different slow-release urea fertilisers, by measuring nitrate and ammonia concentrations in leachate.

This research contributes to the development of sustainable N fertiliser solutions aimed at improving nitrogen use efficiency while addressing the economic and environmental concerns associated with the loss of.

By leveraging slow-release urea fertiliser, the study offers a viable pathway to enhance nitrogen use efficiency, mitigate nitrogen losses, and improve crop productivity in Australian agriculture. The findings will support future advancements in fertiliser technology and sustainable nutrient management practices, ensuring resilience against climate change-induced challenges.

This research is supported by UWA and ARC LP.



Soil organic carbon storage (Mg ha–1) after harvest in 2020 and 2021.

Straw-derived biochar regulates soil enzyme activities, reduces greenhouse gas emissions, and enhances carbon accumulation in farmland under mulching

Project team: Professor Peng Zhang[2] (Project leader; pengzhang121@hotmail.com), Yuhao Wang[2], Zhonghong Tian[2], Xiaoqun Li[2], Mengjie Zhang[2], Yujing Fang[2], Yingzhou Xiang[2], Yuchen Liu[3], Enke Liu[4], Zhikuan Jia[2], Hackett Professor Kadambot H.M. Siddique[1], Wei Ting[2], Weijun Zhang[5].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]The University of Birmingham, UK; [4]Chinese Academy of Agricultural Sciences, China; [5]NingXia Academy of Agricultural and Forestry Sciences, China.

Climate change caused by excessive greenhouse gas emissions (GHGs) has led to extreme weather events and long-term effects on ecosystems. Cultivated dry farmlands comprise 40 % of the world's terrestrial land and they are extremely vulnerable to the effects of climate change. To develop sustainable agriculture, it is important to balance crop productivity with environmental friendliness. The large-scale application of film mulching has enhanced crop productivity by optimizing the soil hydrothermal conditions in arid farmland, especially in China.

This study examines the effects of different carbon (C) inputs—specifically straw and biochar—on soil carbon accumulation, GHG emissions, and soil biochemical properties in dryland farmland under both mulched and non-mulched conditions.

A field experiment was conducted over two growing seasons in Pengyang, Ningxia, China, with six treatments: flat planting without inputs (NN), with straw (NS), or with biochar (NB), and film mulching alone (MN), with straw (MS), or with biochar (MB).

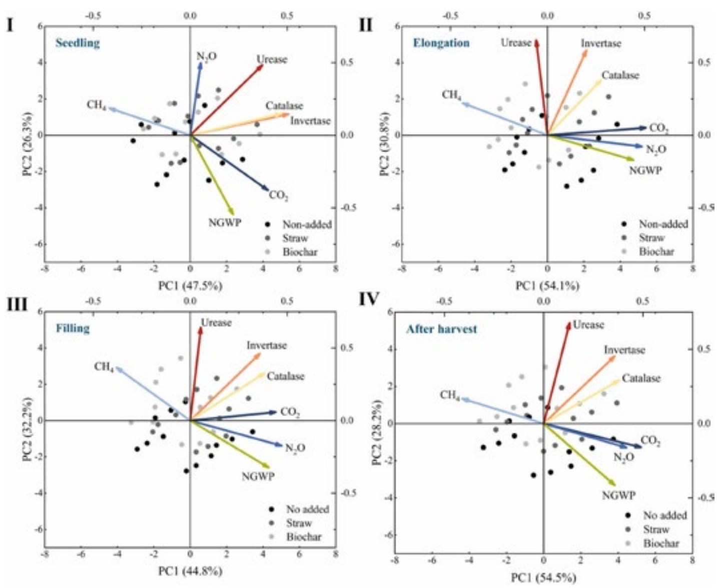
Film mulching was found to improve the soil hydrothermal environment and increase maize yields by 29.3%. However, it also led to a 6.91% decline in soil organic carbon storage (SOCS) and raised GHG emissions, with CO_2 and N_2O increasing by 10.07% and 1.42%, respectively. These results highlight the environmental trade-offs associated with long-term continuous mulching in semiarid regions.

Straw incorporation enhanced plant-fixed C by 14.99% and contributed to nutrient improvement in the soil. Nevertheless, the direct return of fresh straw increased CO_2 and N_2O emissions and reduced methane (CH_4) uptake by 3.78%, likely due to stimulated microbial activity during decomposition before nutrients became available to crops.

In contrast, the incorporation of straw-derived biochar significantly improved outcomes across several indicators. Compared with straw under mulching (MS), biochar treatment (MB) resulted in lower CO_2 (by 9.93%) and N_2O (by 20.97%) emissions, greater CH_4 uptake (10.72%), and higher SOCS (3.42%). Biochar also improved the carbon efficiency ratio (CER) by 26.93% and enhanced soil enzyme activities such as invertase (6.48%) and urease (13.76%), indicating improved nutrient cycling and soil health.

Although both straw and biochar contributed to increased carbon input and crop productivity, biochar was more effective in reducing GHG emissions and improving soil biochemical properties. These findings suggest that combining film mulching with biochar application provides a promising strategy for maintaining soil quality and achieving sustainable agricultural development in semiarid dryland systems.

This research is supported by NNSFC, Ningxia Key Research and Development Program, National Key Research and Development Program of China, Natural Science Basic Research Plan in Shaanxi Province of China.



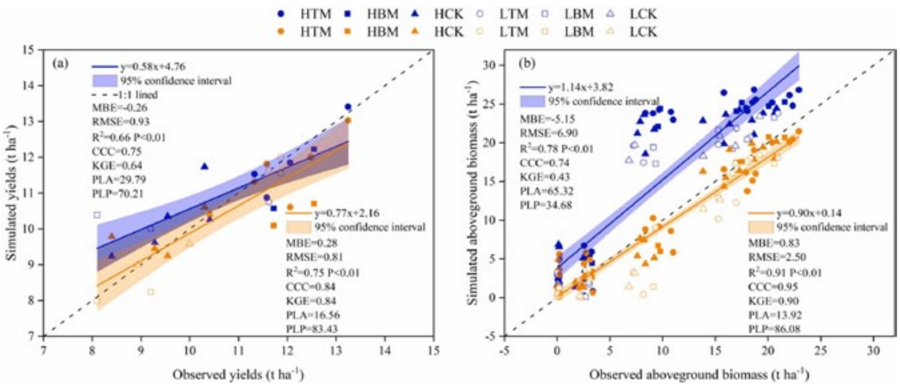
Principal component analysis of soil enzyme (Invertase, Catalase and Urease) activity, cumulative GHG (CO_2, N_2O and CH_4) emissions and NGWP. Note: Panel I–IV shows different growth period (seedling, elongation, filling, and after harvest, respectively).

Incorporating canopy radiation enhances the explanation of maize yield change and increases model accuracy under film mulching

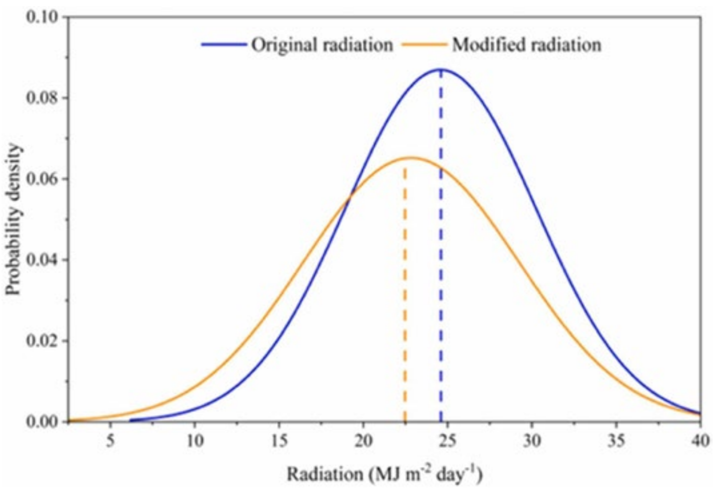
Project team: Professor Bin Wang[3] (Project leader; bin.a.wang@dpi.nsw.gov.au), Professor Hao Feng[2,4] (Project leader; nercwsi@vip.sina.com), Hao Quan[2,3], Lihong Wu[2,3], Hackett Professor Kadambot H.M. Siddique[1], Qin'ge Dong[2,4].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]Charles Sturt University, NSW; [4]Chinese Academy of Sciences and Ministry of Water Resources, China.

Plastic film mulching (PM) is a common practice in dryland agriculture that enhances crop yields and water use efficiency by modifying the soil's thermal and moisture conditions. Its effectiveness depends on the optical properties of the film, which regulate radiation absorption and reflection. However, limited studies have quantified its impact on radiation use efficiency and crop yields, making this research crucial for optimizing agricultural practices.



Verification of (a) maize yield and (b) aboveground biomass under different management practices during maize growing seasons. Blue and orange colors represent simulated results using the SPACSYS model with radiation from the weather station and recalculated radiation considering crop absorption capacity, respectively. MBE: mean bias error, RMSE: root mean square error, R2: coefficient of determination, CCC: concordance correlation coefficient, KGE: Kling-Gupta efficiency, PLA: percentage lack of accuracy, PLP: percentage lack of precision. HTM, HBM, and HCK are transparent film, black film, and no mulching under high nitrogen fertiliser respectively; LTM, LBM, and LCK are transparent film, black film, and no mulching under low nitrogen ffertiliser respectively. R2, CCC, and KGE values very close to 1 suggest an ideal model, while MBE, RMSE, PLA, and PLP approaching 0 indicate increased model efficiency.



Probability density distribution of original and modified radiation during the 2019 and 2020 maize growing seasons. Blue curve represents radiation data sourced from the weather station while orange curve shows estimated radiation considering the crop's absorption capacity. Dashed lines in blue and orange denote the peaks of the original and modified radiation, respectively.

This study evaluated the effects of PM on radiation utilization and maize yield in dryland areas of northwest China. Specifically, the research aimed to explore how different PM colors and nitrogen levels affect the interception and absorption of photosynthetically active radiation (PAR), and how this influences crop radiation use efficiency and maize yields. The two-year experiment involved three PM treatments: transparent film (TM), black film (BM), and no film, alongside two nitrogen fertilization levels (high and low).

The study found that transparent TM led to higher interception and absorption of PAR compared to black film and no film treatments. TM increased radiation use efficiency for intercepted radiation by 10.6% and for absorbed radiation by 9.7%, resulting in a maize yield increase of 9.3–19.2%. In addition, nitrogen fertilization further enhanced these effects, particularly in combination with TM, leading to increased leaf chlorophyll content, higher photosynthesis rates, and a longer grain-filling period. The use of TM also led to a significant improvement in nitrogen use efficiency, with a 25.8–30.2% increase in the partial factor productivity of nitrogen.

Furthermore, the study incorporated canopy radiation data into the SPACSYS crop simulation model, which improved the accuracy of maize biomass and yield predictions. By including the effects of PM on radiation input, the modified model provided more reliable simulations of maize productivity under mulching conditions.

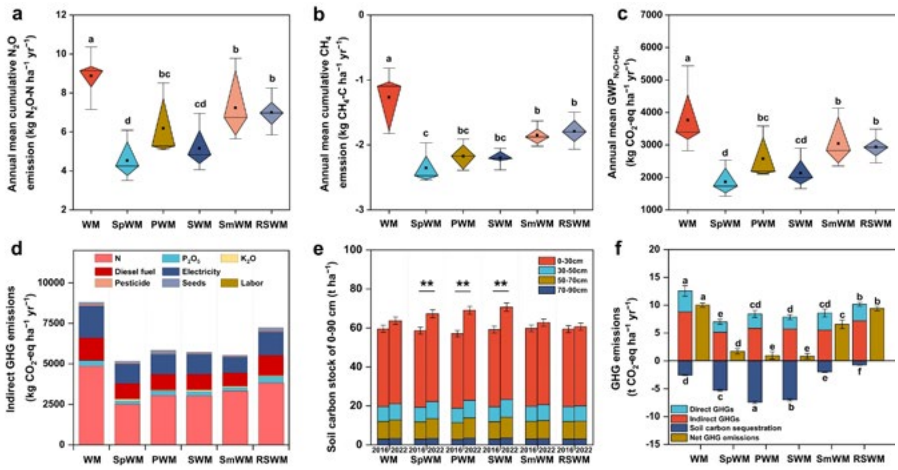
The results highlight the importance of using transparent film mulching and optimal nitrogen management in dryland areas to enhance crop yield. The study recommends that canopy radiation data be incorporated into crop models to improve yield simulations, especially in regions where plastic mulching is commonly applied. These findings provide valuable insights into improving maize production in arid areas, with potential applications for optimizing agricultural practices in other dryland regions worldwide.

This research is supported by NNSFC and the National Key R&D Program of China.

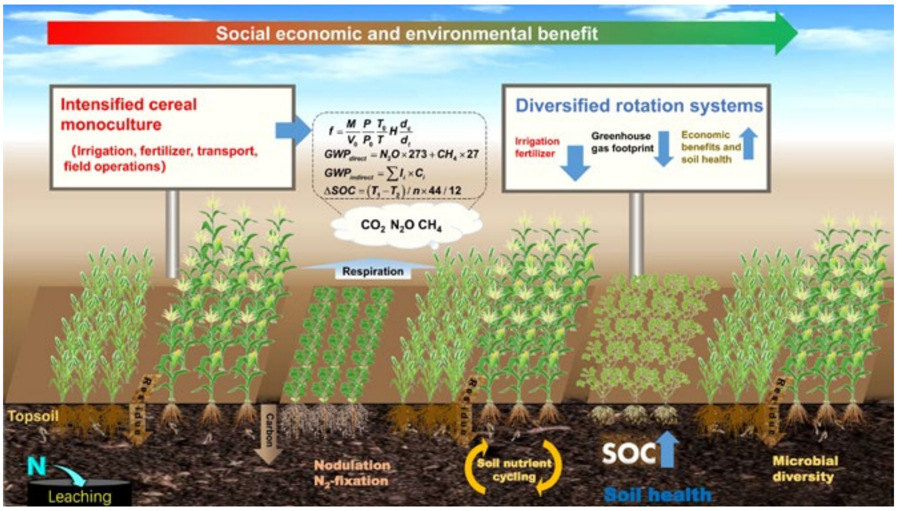
Diversifying crop rotation increases food production, reduces net greenhouse gas emissions, and improves soil health

Project team: Professor Xiaolin Yang[2,3] (Project leader; yangxiaolin429@cau.edu.cn), Jinran Xiong[2,3], Taisheng Du[2,3], Sien Li[2 3], Shaozhong Kang[2,3], Xiaotang Ju[4], Yantai Gan[5,6], Longlong Xia[6], Yanjun Shen[6], Steven Pacenka[7], Tammo S. Steenhuis[7], Klaus Butterbach-Bahl[8], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]China Agricultural University, China; [3]State Key Laboratory of Efficient Utilization of Agricultural Water Resources, China; [4]Hainan University, China; [5]Wenzhou University, China; [6]Chinese Academy of Sciences, China; [7]Cornell University, USA; [8]Aarhus University, Denmark; [9]Karlsruhe Institute of Technology, Germany.



Schematic illustration of system integration from issues to outcomes.



Direct and indirect greenhouse gas (GHG) emissions in the diversified crop rotations.

Diversified cropping systems offer a sustainable solution to increasing agricultural productivity while addressing environmental challenges. This study, conducted over six years in the North China Plain, examines the benefits of integrating cash crops (such as sweet potato) and legumes (peanut and soybean) into the traditional wheat-maize monoculture. The findings reveal that these diversified rotations increase equivalent yield by up to 38%, reduce N_2O emissions by 39%, and improve the system's greenhouse gas balance by 88%. Additionally, the inclusion of legumes enhances soil health, boosting soil organic carbon stocks by 8% and improving soil quality by 45%.

Traditional wheat-maize systems dominate the North China Plain, a highly intensively cultivated region, occupying 70% of the area's arable land. While these systems have significantly contributed to food production, they also pose environmental concerns due to excessive synthetic fertiliser use and associated greenhouse gas emissions. The study aimed to assess various diversified cropping systems in terms of yield, environmental impact, and soil health.

The results show that incorporating legumes in rotations not only increases crop yields but also enhances soil microbial activity, which is crucial for maintaining long-term soil health. These systems help reduce the reliance on synthetic fertilisers, ultimately lowering greenhouse gas emissions and improving the ecological balance. Moreover, the study highlights that diversified rotations can increase cereal production by up to 32% when wheat-maize follows alternative crops in rotation, with farmers' income rising by 20%.

This research provides a valuable case study for sustainable agriculture, demonstrating that crop diversification can improve food production, reduce environmental impact, and promote soil health. The study's findings suggest that large-scale adoption of such practices in the North China Plain could serve as a model for other regions facing similar agricultural and environmental challenges, supporting long-term agricultural resilience and sustainability.

This research is supported by NNSFC, the Hebei Province Key Research and Development Program of China and Pioneer Center for Research in Sustainable Agricultural Futures.

Spatial and temporal distribution of faba bean gall (*Physoderma*) disease and its association with biophysical factors in Ethiopia

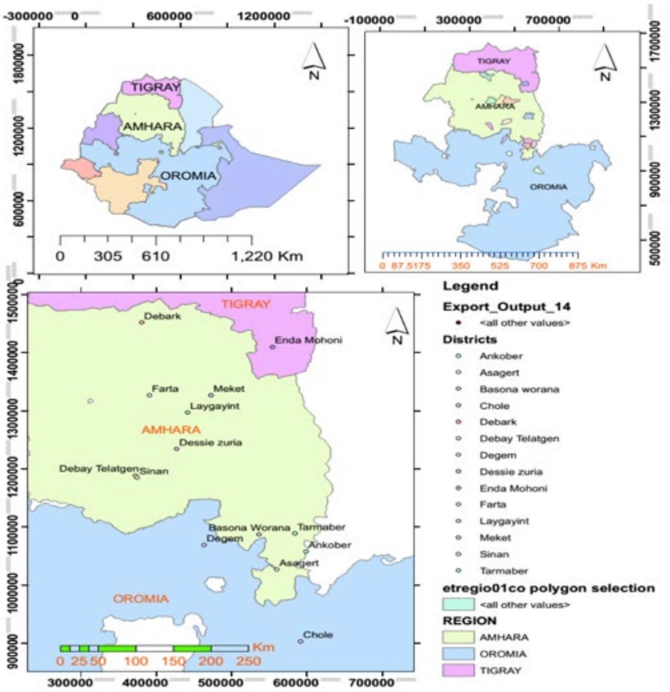
Project team: Professor Beyene Bitew[3] (Project leader; beyenebitew@yahoo.com), [1]Professor Martin Barbetti, Chemeda Finisa[2], Habtamu Terefe[2], Seid Ahmed[4].

Collaborating organisations: [1]UWA; [2]Haramaya University, Ethiopia; [3]Debre Birhan Agricultural Research Center, Ethiopia; [4]International Center for Agricultural Research in the Dry Areas, Morocco.

This study examined the impact of the faba bean gall (FBG) disease caused by the fungus *Physoderma* in Ethiopia. FBG disease has become a significant issue in the country's faba bean production, with field surveys conducted across 14 districts in 2018 and 2019. The disease was found in all surveyed districts, with varying levels of severity and incidence, particularly in the Sinan and Ankober districts. The research highlighted that factors such as high altitude (≥2700 m), poorly drained soils, dense crops and weeds, and certain growth stages contributed to increased disease severity. Manure application, early or late planting, and crop density were also found to exacerbate the disease.

Faba bean is a crucial crop in Ethiopia, contributing to food security, soil fertility, and animal feed. Despite its genetic diversity and benefits, productivity is low, largely due to diseases like FBG and other constraints, such as poor access to improved seed varieties. The disease, first identified in 2011, has spread across multiple regions, causing total crop failure in severe cases. The pathogen survives on infected plant debris, creating a persistent problem.

The study suggests that improving soil drainage, managing weeds, adjusting planting density, and adhering to recommended planting times can mitigate the disease's spread. Additionally, the use of nitrogen, phosphorus, and sulfur fertiliser and the development of resistant varieties are recommended. An integrated disease management strategy tailored to the conditions of the affected regions is essential for controlling FBG disease and improving faba bean production in Ethiopia.



Map showing the districts of the FBG disease survey in three national regional states of Ethiopia, during the 2018 and 2019 cropping seasons.

FBG disease symptoms on faba bean leaf (A), stem (B), root area (C), flower (D), and pod (E).

Given the significant impact of FBG on faba bean yields, especially in Ethiopia's highland areas, the study calls for a coordinated effort in disease management and the development of tolerant varieties to safeguard the crop's future.

This research is supported by ARARI, ICARDA and Africa RISING/USAID through ICARDA.

Granulated biosolids compost: turning waste into a cropping input

Field trial at the DPIRD Katanning Research Station. Image taken 21 July 2024.

Honours student Darren de Vos.

Project team: Professor Megan Ryan[1] (Project leader; megan.ryan@uwa.edu.au), Mr Darren de Vos[2], Dr Bede Mickan[1], Dr Craig Scanlan[2], Evonne Walker[1], Mr George Mercer[1].

Collaborating organisations: [1]UWA; [2]DPIRD; Richgro.

Can we turn biosolids waste into an effective product for use alongside mineral fertilisers? We proposed to answer this question through a field trial at DPIRD Katanning Research Station. Funding was provided through the ARC Training Centre for the Transformation of Australia's Biosolids Resource program and DPIRD's Climate Resilience Program's Katanning Research Station: Carbon Neutral 2030 project.

Farmers have long used compost in intensive agriculture. However, due to compost's low nutrient density, high transportation cost, and high application cost, compost has not been widely adopted in cereal crops. Forming compost into granules for application through standard crop seeding equipment opens new opportunities to use compost across all agricultural regions. Researchers have rarely investigated the agronomic impact of using granulated compost as a cereal fertiliser.

Through a field trial, we aimed to assess the impact of partially substituting mineral nitrogen (urea) with organic nitrogen in the form of granulated compost at rates of 5 %, 10 % and 20 % of total nitrogen. We hypothesised that the organo-mineral blends would mineralise more slowly than mineral-only blends, reducing nitrogen losses and improving yield.

Progress and Highlights from 2024

In a one-year trial, we observed that organo-mineral blends did not improve crop yields over mineral-only treatments. However, compost granules remained in the soil after the growing season, indicating incomplete mineralisation. As a result, the expected nutrients from the compost were not readily available to plants, leading to lower than expected yields. The below-average growing season rainfall may have contributed to the incomplete granule breakdown. Consistent with this observation, measurements of microbial biomass nitrogen showed no differences across treatments.

Further breakdown of granules and mineralisation is expected in subsequent years; therefore, further research should focus on conducting multi-year trials to assess the impact of longer-term organic use.

This research will help Western Australian wheat farmers understand the benefits and limitations of organo-mineral nutrient blends and inform decisions regarding nutrient inputs amid the increased focus on costs, emissions, and sustainability.

Furthermore, this study will help compost producers develop products that perform effectively in agricultural settings.

This research is supported by DPIRD Climate Resilience Program and ARC for the Transformation of Australia's Biosolids Resource.

Exploring microbial diversity and antimicrobial resistance in conventional and biological farming systems

Project team: Associate Professor Zakaria Solaiman[1] (Project leader; zakaria.solaiman@uwa.edu.au), Professor Zed Rengel[1], Mr Mostarak Hossain Munshi[1], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; Troforte Innovations Pty Ltd.

Soil health, crucial for sustainable agriculture, is significantly influenced by microbial diversity, which supports nutrient cycling, carbon storage, and disease suppression. Conventional farming practices, which rely heavily on the use of synthetic fertilisers and pesticides to boost crop yields, can adversely affect soil microbial communities and promote antimicrobial resistance (AMR).

AMR is a critical global health issue, with projections indicating it could cause millions of deaths annually by 2050. Conversely, biological farming practices avoid synthetic inputs and typically foster higher soil carbon and microbial activity. However, they sometimes have inconsistent effects on microbial diversity compared to conventional methods. Moreover, biological farming often uses composts and animal manure, which can introduce antimicrobial inputs and potentially exacerbate AMR. Therefore, sustainable agricultural practices that optimise crop yields while enhancing soil microbial diversity and mitigating AMR.

A promising approach involves incorporating rock mineral fertilisers with microbial inoculants, providing natural mineral nutrients, and encouraging beneficial microbial activity. While these methods show potential in increasing crop yields, their effects on microbial community composition, diversity and AMR dynamics remain underexplored.

This research aims to analyse soil microbial diversity and AMR profiles under long-term conventional and biological farming systems, investigate the effects of different fertilisers (synthetic vs. biofertiliser), herbicides and fungicides on microbial diversity and AMR genes, and examine the impact of rock mineral fertilisers combined with microbial inoculants on soil microbial communities and AMR dynamics.

This research is supported by CRC - SAAFE.

PhD student Munshi Mostarak's project proposal poster presentation.

Pre-breeding of canola and field peas

Project team: Professor Wallace Cowling[1] (Project leader; wallace.cowling@uwa.edu.au), Jasenka Vuksic[1], Rozlyn Ezzy[1], Felipe Castro-Urrea[1].

Collaborating organisation: [1]UWA.

In 2024, we continued our long association with plant breeding company NPZ Lembke in Germany, who have funded projects at UWA since 2000 for pre-breeding of canola (known as spring oilseed rape or 'raps' in Germany) and field peas. In these projects, we have showcased the industry impact of UWA research, with 37 new canola varieties released since 2003 by NPZ and associated companies in southern Australia. These varieties have added significant value to Australian canola growers.

In 2024, the canola breeding project successfully produced over 150 crosses in the glasshouse, following an optimised crossing design which aimed to maximise hybrid performance in the progeny. Field trials occurred at 9 locations across southern Australia and included more than 15,000 plots which were assessed for grain yield, seed oil and protein, blackleg disease resistance, and appropriate flowering and maturity dates for agronomic adaptation to southern Australia. Field trial data were analysed with the latest statistical models to detect and select the highest performing lines and hybrids.

In the pea pre-breeding project, PhD student Felipe Castro-Urrea used whole-genome markers to evaluate genomic prediction for low-heritability traits in field peas. These traits included stem strength, black spot resistance, and grain yield. Statistical models to predict performance across glasshouse and field trials were developed, achieving high accuracy of prediction and enabling selection of non-phenotyped candidates. Additionally, 12 promising candidates with high yield and increased lodging resistance were identified in the analysis of the first commercial-scale field trial at Boddington WA.

This research is funded by UWA and NPZ Lembke, Germany.

Senior Technician Rozlyn Ezzy and NPZA canola breeding project Technical Operations Manager Jasenka Vuksic in the glasshouse during annual crossing of canola plants.

Field pea field trial at Boddington, Western Australia.

Group photograph at ACIAR project CROP/2018/132 annual meeting at Kisumu, Kenya, May 2024.

Rapid breeding for reduced cooking time and enhanced nutritional quality in common bean (*Phaseolus vulgaris*)

Project team: Professor Wallace Cowling[1] (Project leader; wallace.cowling@uwa.edu.au), Dr Renu Saradadevi[1], Hackett Professor Kadambot H.M Siddique[1], Dr Clare Mukankusi[2], Winnifred Amongi[2], Jean-Claude Rubyogo[3], Annuarite Uwera[4], Abel Moges[5], Blaise Ndabashinze[6], Julius Mbiu[7], Shamir Misango[8], Dr Stanley Nkalubo[9].

Collaborating organisations: [1]UWA; [2]Alliance-UGA; [3]PABRA; [4]Alliance-TZA; [4]RADB Rwanda; [5]EIAR Ethiopia; [6]ISABU Burundi; [7]TARI Tanzania; [8]KARLO Kenya; [9]NaCRRI Uganda.

This ACIAR project is led by Professor Wallace Cowling and Research Associate Dr Renu Saradadevi at UWA. The team includes bean breeders at The Alliance of Bioversity and CIAT in Uganda (Alliance-CIAT), the Pan Africa Bean Research Alliance (PABRA), and in six partner countries in East Africa. The Australian team includes Dr Li Li and Emeritus Professor Brian Kinghorn at University of New England, Australia.

Cooking beans for tasting differences between varieties, at KALRO Kakamega Research Station, Kenya, May 2024.

During five years of the project from 2019 to 2024, the project successfully bred for shorter cooking time in African common bean: cycle 2 progeny were 28% faster-cooking than cycle 1 progeny. The project employs new breeding methods based on pedigree and genomic information together with optimal contribution selection to accelerate the breeding of high-yielding and rapid cooking common bean. This breeding method is known by the acronym BRIO (https://research.aciar.gov.au/rapidcookingbeans/brio).

Progeny seeds are sent out to six partner countries for testing in field trials for grain yield and other traits of interest such as disease and pest resistance. As a result, grain yield also increased by 6% from cycle 1 to cycle 2 in this project.

Partner countries share data through the BMS database for selecting progeny for further testing in their region and to advance new potential new varieties within their preferred market classes. Subsequently, new bean varieties will be released into relevant markets in East Africa through the Alliance-CIAT and PABRA networks and with the involvement of African farmers in participatory variety selection.

In 2024, the project annual meeting was held at Kisumu, Kenya, on beautiful Lake Victoria. In addition to project partners, a large group of supporters from government and industry were present and urged continued work on the project. As part of the AGM, a participatory variety selection event was organised at KALRO, Kakamega, bringing together farmers and bean value chain representatives such as seed processors. Participants, including men and women, evaluated Rapid Cooking Bean Project (RCBP) bean varieties grown in the field, scoring them based on agronomic performance. Additionally, they conducted a sensory evaluation by tasting the cooked beans and providing feedback on key traits such as colour, texture and flavour. This engagement ensured that consumer preferences were considered in variety selection, promoting the adoption of beans that meet market demands.

Participatory variety selection in the bean experimental field at KALRO Kakamega Research Station, Kenya, May 2024.

This research is supported by the ACIAR Project CROP/2018/132.

Expanding phenological diversity in narrow-leafed lupin using novel flowering time genes

Project team: Professor Wallace Cowling[1] (Project leader; wallace.cowling@uwa.edu.au), Karen Nelson[1], Dr Aneeta Pradhan[1].

Collaborating organisations: [1]UWA.

This project began at UWA in September 2023 with the aim of transferring a new flowering time gene (*pal*) from wild lupins to elite cultivated lupin varieties. The project is undertaking rapid backcrossing of the new gene to elite lupin cultivars with the aid of molecular markers. This project builds on previous research at UWA funded by GRDC and COGGO Research Fund with industry collaborator Australian Grain Technologies Pty Ltd.

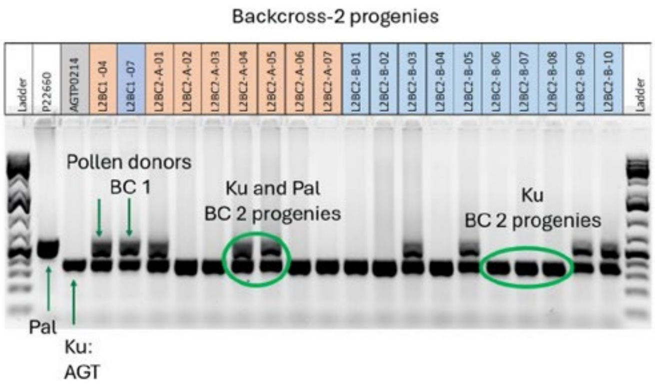
A single early flowering gene has been the favoured gene to breed early-flowering narrow-leafed lupins adapted to the main wheatbelt of Western Australia since the 1960s, and this project will increase the diversity of flowering time in future lupin varieties with the new *pal* gene. The goal is to expand the range of environments for lupin production in southern Australia. The new *pal* gene delays flowering by 5 to 15 days.

Current lupin varieties are poorly adapted to early sowing and flower too early for longer growing seasons in higher rainfall zones. This project will enhance the phenological diversity of commercially cultivated lupins available to Australian lupin breeders. The new *pal* gene will provide Australian lupin growers with new mid-season lupin varieties which are adapted to early sowing in the main wheatbelt, and to higher rainfall zones. The new varieties should have higher yield potential and higher harvest height.

This research was supported by the GRDC project UWA2307-004RTX and COGGO Research Fund, with industry collaborator AGT Pty Ltd.

UWA Research Officers Karen Nelson (left) and Dr Aneeta Pradhan (right) with Professor Wallace Cowling in the rapid-cycle growth room for rapid backcrossing of the new lupin flowering gene into cultivated varieties.

Backcross 4 seedlings in the rapid-cycle growth room.



Gel showing molecular markers for the pal and Ku genes with Backcross 1 pollen donors (heterozygous for the pal gene) and segregating Backcross 2 progenies.

Responses of phosphate-solubilizing and nitrogen-fixing bacteria to soil compaction and phosphorus application in peanut rhizosphere

Project team: Pu Shen[2] (Project leader; shenpupeanut@126.com), Dr Yinglong Chen[1], Dianxu Chen[2], Miao Liu[2], Haiyan Liang[2], Liyu Yang[2], Qi Wu[2].

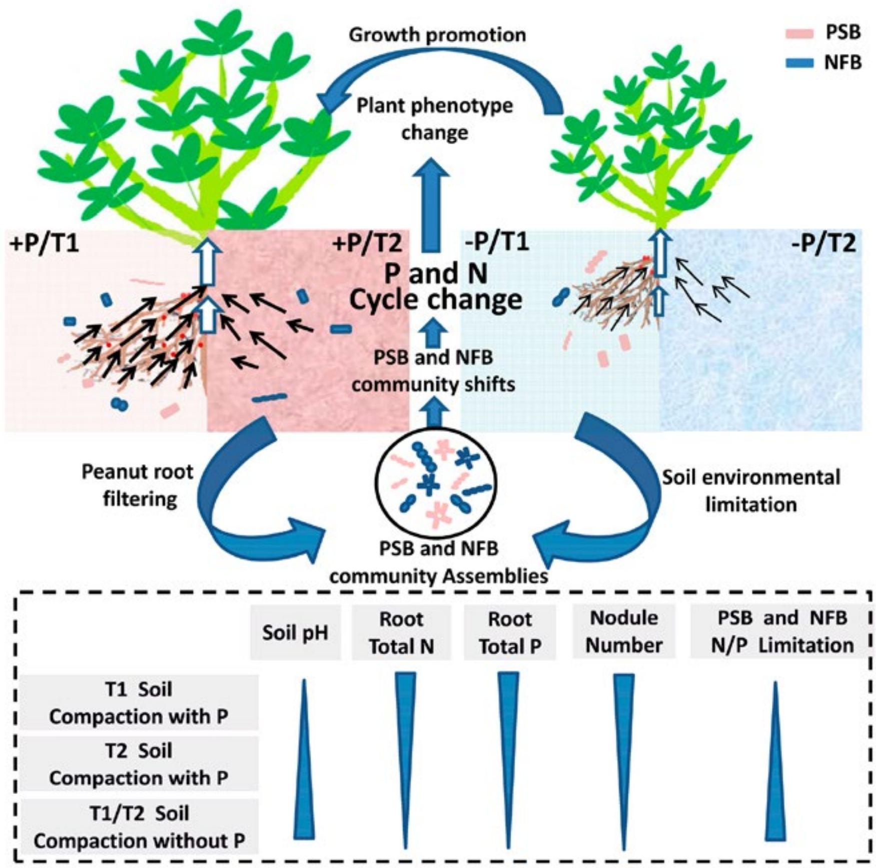
Collaborating organisations: [1]UWA; [2]Shandong Academy of Agricultural Sciences, China.

Soil properties, particularly compaction and nutrient availability, significantly influence the structure and function of rhizosphere microbial communities. However, there is limited understanding of how soil compaction and phosphorus (P) application affect phosphate-solubilizing bacteria (PSB) and nitrogen-fixing bacteria (NFB). This study investigated the responses of PSB and NFB communities in the rhizosphere of peanut (Arachis hypogaea L.) under different levels of soil compaction and phosphorus input.

A controlled pot experiment was conducted using the peanut cultivar Hua Yu 22. Treatments included two soil compaction levels and two P levels. Results indicated that PSB community composition was strongly influenced by soil available phosphorus, acid phosphatase activity, nitrogenase activity, and compaction level. For NFB, shifts in operational taxonomic units (OTUs) were primarily associated with soil available phosphorus and compaction. Network analysis revealed greater community complexity among PSB compared to NFB, while NFB networks exhibited stronger negative correlations among taxa. Community assembly analysis suggested that PSB were mainly shaped by stochastic drift processes, whereas NFB were influenced by both drift and homogenizing selection. Both microbial groups responded significantly to phosphorus limitation and increased soil compaction.

These findings improve our understanding of the ecological dynamics of beneficial rhizosphere microbes under abiotic stress. The study provides valuable insights for enhancing peanut production in compacted and phosphorus-deficient soils. Moreover, the key PSB and NFB taxa identified through network interactions present promising candidates for developing microbial inoculants aimed at mitigating soil compaction and improving nutrient availability.

This research was supported by Shandong Provincial Natural Science Foundation, Agricultural Science and Technology Innovation Engineering of Shandong Academy of Agricultural Sciences, Major Scientific and Technological Innovation Projects in Shandong Province, Key R & D Program of Shandong Province and ARC.



A summary of the effects of different soil compactions and phosphorus applications on peanut plants, phosphate-solubilizing and nitrogen-fixing bacteria communities, and soil nutrient availability.

Gaus Azam operating a single row seeder for planting wheat crop in the experiment near Kalannie, Western Australia.

Gaus Azam operating a rotary hoe for loosening and incorporation of lime in the experiment near Kalannie, Western Australia.

Unlocking the secrets of soil health: how addressing acidity and compaction enhances root development and crop yield

Project team: Dr Gaus Azam[1] (Project leader; gaus.azam@dpird.wa.gov.au), Kanch Wickramarachchi[2], Dianxu Chen[2], Dr Craig Scanlan[2], Dr Yinglong Chen[1].

Collaborating organisations: [1]UWA; [2]DPIRD.

Subsoil acidity and compaction are common challenges that often occur together, yet their combined impact on root development and crop performance under water-limited conditions remains poorly understood. Our recent study set out to explore how improving soil strength and acidity could influence root growth, and how these changes affect overall crop health and yield.

Using state-of-the-art rhizotron facilities, researchers captured real-time images of root growth in situ during wheat growing season. The study focused on understanding the temporal effects of soil improvement techniques—specifically, soil loosening and lime incorporation—on root development. By examining these root system dynamics alongside water and nutrient uptake, the team sought to uncover how better soil conditions could drive improved crop performance.

The results were telling: improving soil conditions through loosening and lime treatment significantly enhanced the planar root length density (pRLD), a key indicator of root growth. This improvement was most noticeable in the subsoil, where wheat roots elongated and proliferated more effectively. Interestingly, regression analysis revealed that subsoil strength—rather than soil pH or aluminum toxicity—had the greatest influence on pRLD in the wheat crop. The enhanced root growth allowed the plants to take up more water, leading to increased wheat head density and higher yields. Beyond loosening the soil, the incorporation of lime proved crucial for reducing soil acidity. This not only allowed for continuous root growth but also promoted the development of root hairs, which in turn enabled the plants to access previously unavailable nutrients. As a result, wheat yield saw further improvement.

This study underscores the importance of addressing multiple soil constraints—both acidity and compaction—when managing soils for optimal crop productivity. By combining root growth imaging with soil property data, researchers have gained valuable insights into root-soil interactions, offering a clearer path to developing sustainable soil management practices that can boost crop yields, especially under challenging growing conditions. Ultimately, this research highlights a critical takeaway for farmers and agronomists: by managing both soil strength and acidity, it's possible to create a thriving root system that enhances water and nutrient uptake, paving the way for healthier crops and improved yields.

This research was supported by DPIRD, GRDC and ARC.

Clay induced organic carbon stabilisation in bio-waste and its application in soil organic carbon sequestration

Project team: Professor Nanthi Bolan[1] (Project leader; nanthi.bolan@uwa.edu.au), Associate Professor Zakaria Solaiman[1], Hackett Professor Kadambot H.M. Siddique[1], Ms Zahra Nizbat[1].

Collaborating organisations: [1]UWA; [2]DPIRD.

Soil carbon (C) sequestration is increasingly recognised as a vital strategy to mitigate global climate change through enhanced storage of organic C in soils. Organic amendments, such as composts and animal manures, improve soil fertility and have the potential for significant C sequestration. However, the rapid microbial decomposition of these amendments often limits their efficacy by releasing carbon dioxide (CO_2) back into the atmosphere. This PhD project addresses this critical gap by exploring innovative methods to stabilise carbon in organic amendments, specifically through chemical immobilisation using clay additives. Such additives offer a large reactive surface area, facilitating the adsorption and stabilisation of C compounds.

The overarching aim of this research is to stabilise carbon in organic amendments with clay additives, thereby enhancing their long-term carbon sequestration potential without compromising their fertilisation value. The research aims to characterise various organic amendments' physical, chemical, and biological properties, investigate the effectiveness of different clay additives in stabilising carbon, evaluate the carbon sequestration potential and fertilisation value of clay-stabilised organic amendments, and assess their impacts on soil microbial activity and enzyme functions.

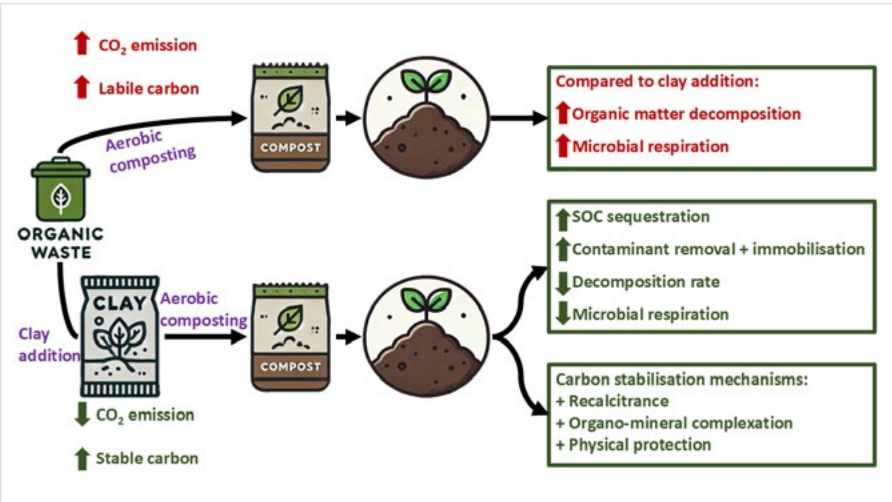
A significant milestone reached in 2024 was the successful completion of a comprehensive glasshouse experiment. This trial evaluated wheat plant growth and grain yield responses and carbon sequestration potential using clay-amended organic amendments across various treatments. Initial findings indicate positive results, with clay-stabilised compost demonstrating enhanced carbon retention, minimal impacts on nutrient availability, and promising improvements in plant biomass, grain yield and overall soil health.

This outcome provides critical insights into the practical application and potential scalability of clay-based stabilisation strategies, representing a substantial step forward in carbon management practices.

This project contributes significantly to sustainable agriculture and climate change mitigation by advancing scientific understanding of carbon stabilisation in soil amendments. By successfully demonstrating that clay nanoparticles can effectively immobilise organic carbon, this research provides practical, scalable solutions for enhancing soil carbon storage, improving soil health, and promoting agricultural sustainability. These innovations have profound implications for policy development and agricultural practices aimed at reducing greenhouse gas emissions and combatting climate change.

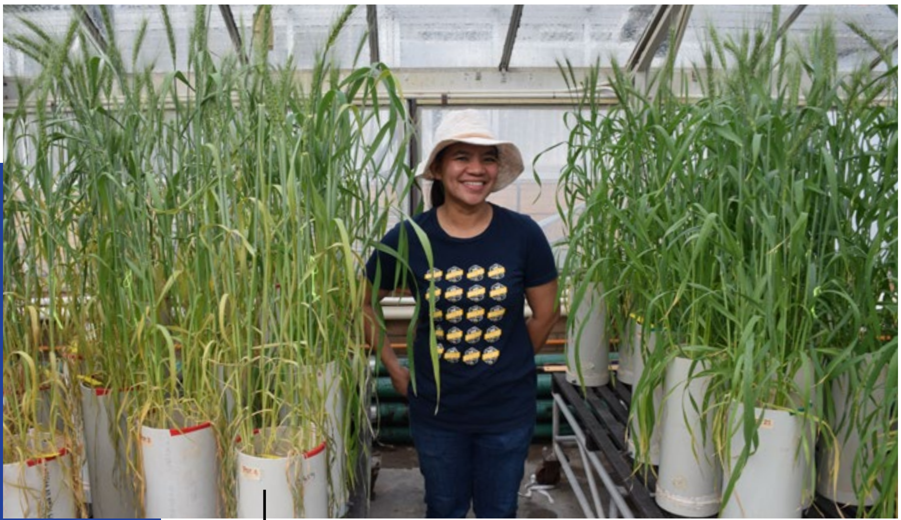
This research was supported by DAAF's National Soil Strategy, Soil Science Challenge Project: "Soil biological mechanisms underpinning the effects of biological amendments on soil health, productivity and resilience".

PhD student Zahra Nizbat (centre) alongside supervisors Professor Kadambot Siddique (left) and Associate Professor Zakaria Solaiman (right) during the wheat glasshouse experiment.



The process of stabilising organic amendments with clay additives to enhance carbon sequestration, improve soil fertility, and mitigate greenhouse gas emissions.

SNP array genotyping of NILs facilitated identifying candidate genes and SNPs associated with drought tolerance in wheat



PhD student Joanne Caguiat with experimental set-up of drought tolerance screening at the plant growth facilities of The University of Western Australia.

Project team: Hackett Professor Kadambot H.M. Siddique[1] (Project leader; kadambot.siddique@uwa.edu.au), Professor Guijun Yan[1], Dr Sultan Mia[1,2], Dr Hui Liu[1].

Collaborating organisations: [1]UWA; [2]DPIRD.

Drought is one of the major abiotic stresses limiting crop yield and productivity in wheat. Breeding for drought tolerance is difficult because it is controlled by quantitative genes making it complex in nature.

Despite several genes and markers reported associated with drought tolerance in wheat, breeding for drought tolerance in wheat is still challenging. To address this, we developed NILs targeting a major effect yield QTL through a fast-generation cycling system combined with marker-assisted selection. Developing near-isogenic lines (NILs) carrying major QTL with contrasting effects and characterising them with SNP array can effectively identify key genes and advance our understanding of the relevant genetic mechanisms for drought tolerance.

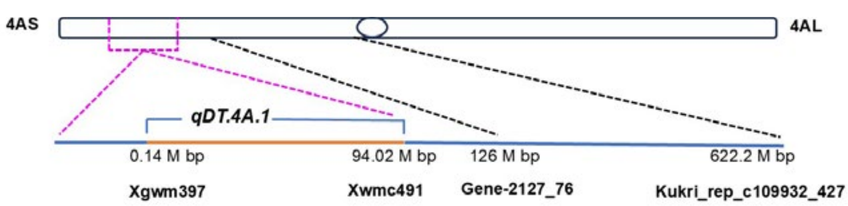
This study aims to characterise the NILs in response to drought stress, identify candidate genes and SNP markers for a major QTL on chromosome 4A associated with drought tolerance traits and further understand the genetic mechanism underlying drought tolerance. The NILs were screened under drought and well-watered conditions and genotyped using a 90K SNP array.

Results showed significant variations in yield and thousand-grain weight among NIL isolines. NILs carrying the positive alleles had higher yield and TGW as compared with those with negative alleles under drought stress conditions depicting the QTL effect to withstand drought.

Using phenotype-genotype association analysis, we identified two SNP markers (Kukri_rep_c109932_427 and GENE-2127_76) near the target QTL on chromosome 4A locus. These SNP markers were linked with six candidate genes encoding proteins associated with drought tolerance. Based on in-silico analyses, expressions of these candidate genes were significantly higher in grain tissues under drought as compared to well-watered condition, confirming their roles in grain-related traits under drought. Further confirmation and validation through transcriptomic and proteomics approaches are warranted to verify and understand their functions and associations with drought tolerance.

Future research should also delve into fine mapping to narrow down the targeted region of interest. Conversion of identified SNPs into KASP markers will also accelerate the selection and identification of breeding lines through marker-assisted selection activities. The identified SNP markers and candidate genes in this study will contribute to a better understanding of drought tolerance in wheat.

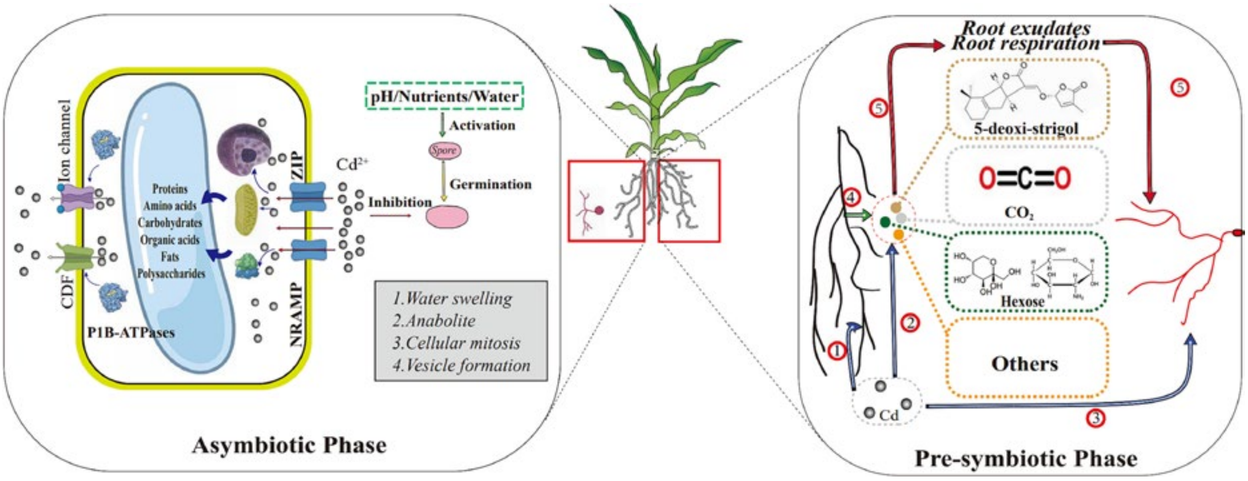
This research was supported by Global Innovation Linkage program (GIL53853) from ADISER and UWA. Joanne Caguiat was supported by the Department of Science and Technology-Science Education Institute Foreign Graduate Scholarships Philippines and Philippine Rice Research Institute.



Physical distance and length of identified SNP in chromosome 4A.

SNP	Start	End	Length
GENE-2127_76	126,012,567	126,012,663	97 bp
Kukri_rep_c109932_427	622,190,951	622,191,051	101 bp

Physical position of SNP markers Gene-2127_75 and Kukri_rep_c109932_427 on wheat chromosome 4A with genotype-phenotype associations in three NIL pairs. Purple dashed line is the peak region of the target QTL qDT.4A.1.



The mechanism of Cd stress on the colonization of arbuscular mycorrhizal fungi (from asymbiotic phase and pre-symbiotic phase).

Understanding the role of arbuscular mycorrhizal fungi in alleviating soil cadmium toxicity in maize

Project team: Dr Yinglong Chen[1] (Project leader; yinglong.chen@uwa.edu.au), Qiqiang Kuang[2], Dr Yujie Wu[2], Yamin Gao[2], Tingting An[2], Shuo Liu[2], Liyan Liang[2], Professor Bingcheng Xu[2], Professor Suiqi Zhang[2], Professor Min Yu[3], Professor Sergey Shabala[1].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]Foshan University, China.

Soil cadmium (Cd) pollution is a growing environmental concern with serious implications for global food security and human health. Cd, a heavy metal, can accumulate in crops, making them unsafe for consumption and threatening agricultural productivity. Our research has focused on the potential of arbuscular mycorrhizal (AM) fungi to mitigate the harmful effects of various heavy metals, including Cd, on crops.

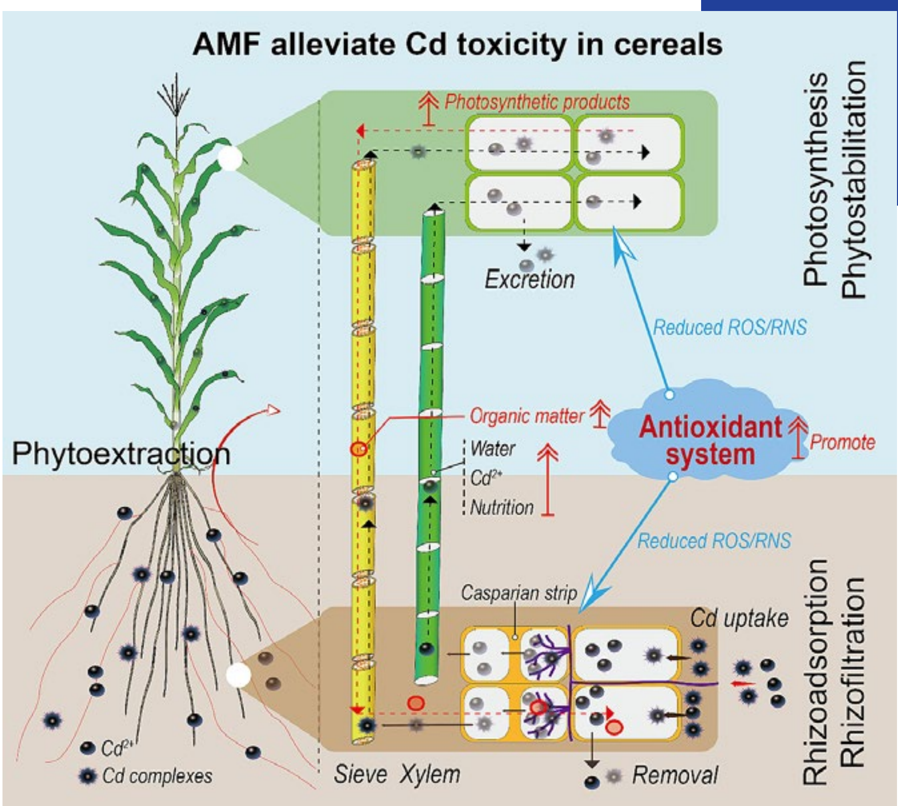
Our recent study investigated the role of AM fungi in protecting maize from Cd toxicity. Researchers studied two maize genotypes: Zhengdan958, which is tolerant to Cd, and Zhongke11, which is sensitive to Cd. The goal was to better understand how maize responds to Cd stress when in symbiosis with AM fungi. The study was conducted through rhizobox experiments, where maize plants were grown with and without AM inoculation, alongside Cd treatment.

The findings were striking. Cd stress severely hindered growth and root development in both maize genotypes. However, plants that were inoculated with AM fungi showed significant improvements across several growth parameters. These included plant height, stem diameter, biomass, root morphology, photosynthetic capacity, and nutrient uptake. In addition, AM fungi enhanced antioxidant enzyme activity, reduced lipid peroxidation, and decreased Cd accumulation in the shoots.

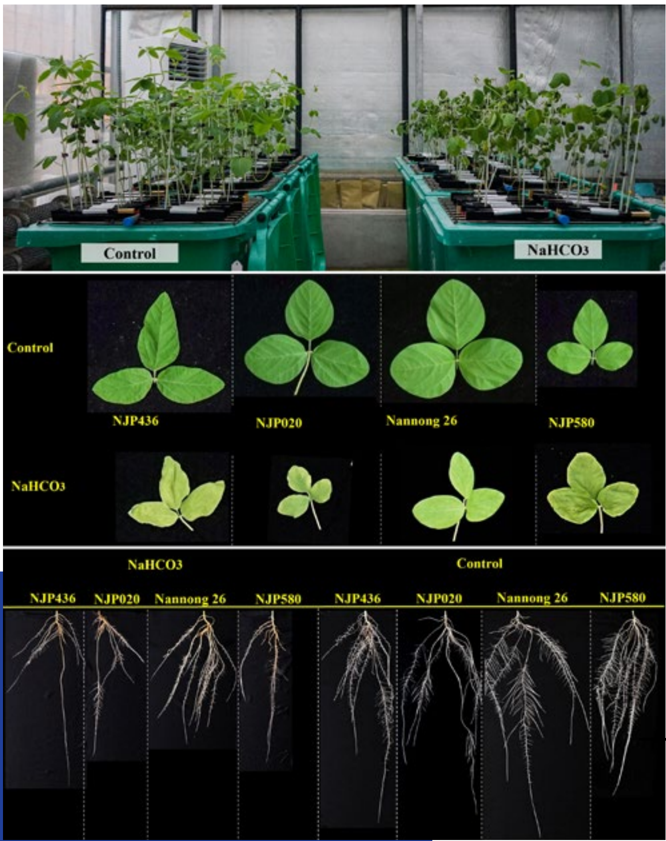
One of the most notable results was the more pronounced effect of AM symbiosis on Zhongke11, the Cd-sensitive genotype. For example, AM symbiosis led to a 55% increase in stem diameter, a 118% increase in root dry weight, and a 42% boost in root superoxide dismutase activity. Additionally, peroxidase activity in roots increased by 209%, and the shoot translocation factor decreased by 77%, reflecting a more efficient response to Cd stress.

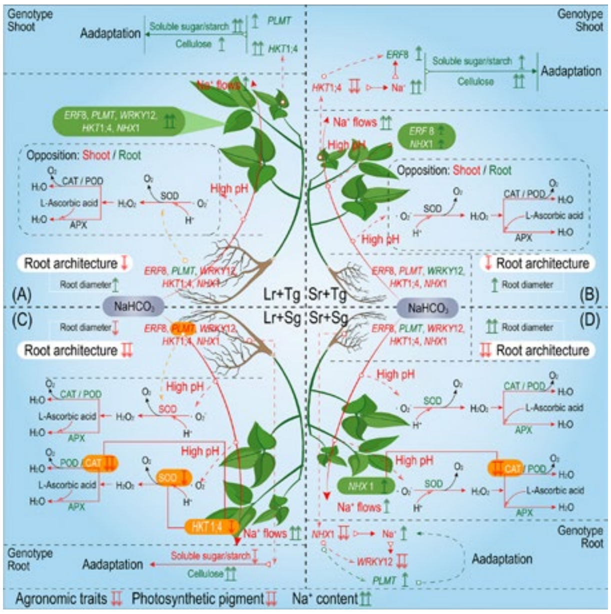
In summary, this study shows that AM fungi help alleviate Cd toxicity in maize through several mechanisms, including enhanced photosynthesis, better nutrient uptake, improved antioxidant defense, and the regulation of Cd transport and accumulation. These findings provide valuable insights for utilizing Cd-tolerant maize genotypes and AM symbiosis as strategies to manage soils contaminated with cadmium. This research holds promise for improving crop resilience in polluted environments, ensuring food safety, and supporting sustainable agriculture practices.

This research was supported by NNSFC ARC and Northwest A&F University, China.



Graphical abstract.





A schematic representation of saline–alkaline tolerance in soybean genotypes with divergent root systems (Lr large root system; Sr. small root system; Tg tolerant genotype; Sg sensitive genotype).

Soybean plants cultivated for 30 days after transferred in a semi-hydroponic system with NaHCO3 or without NaHCO3 (control) for five days (treatment). The lower panels show example third compound leaves and root systems of four selected genotypes (bar = 10 cm).

Exploring genotypic variations in soybean root morphology and saline-alkaline tolerance

Project team: Dr Yinglong Chen[1] (Project leader; yinglong.chen@uwa.edu.au), Shuo Liu[2], Dr Tingting An[2], Yamin Gao[2], Qiqiang Kuang[2], Professor Bingcheng Xu[2], Professor Suiqi Zhang[2], Professor Xiping Deng[2], Professor Tuanjie Zhao[3], Professor Hon-Ming Lam[4], Professor Sergey Shabala[1].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]Nanjing Agricultural University, China; [4]The Chinese University of Hong Kong, China.

Soybean (Glycine max L. Merr.) is highly sensitive to saline-alkaline conditions, exhibiting considerable genotypic variability in its tolerance to these stresses. While it is well-established that the root system plays a critical role in resisting saline-alkaline stress, the specific mechanisms, especially those related to root morphological traits, remain poorly understood.

This study focused on eight soybean genotypes with differing root system sizes to investigate their tolerance to saline-alkaline stress. The plants were subjected to NaHCO3 stress (0 and 30 mmol L^{-1}) for five days from 26 days after transplantation, using a semi-hydroponic phenotyping platform.

The results highlighted significant variations in 20 shoot and root traits, as well as 23 physiological and biochemical characteristics, under saline-alkaline stress. Key findings from the research include differential expression of genes associated with stress tolerance, such as *GmHKT1;4*, *GmPLMT*, *GmERF8*, and *GmWRKY12*. These genes were found to play a critical role in the plant's response to saline-alkaline stress. Based on the relative shoot dry mass ratio, the eight genotypes were categorised into three groups: sensitive, moderately tolerant, and tolerant.

Notably, two genotypes demonstrated distinct mechanisms for coping with saline-alkaline stress. The genotype Nannong 26, which has a large root system, showed increased calcium (Ca^{2+}) accumulation and up-regulation of *GmHKT1;4* and *GmPLMT* in both the shoots and roots. In contrast, the genotype NJP580, which has a smaller root system, exhibited higher potassium (K^+) accumulation and up-regulation of GmERF8 and GmWRKY12 in both tissues. Several root traits emerged as potential indicators of saline-alkaline tolerance, including root dry mass, fine root length, and the upper-to-lower biomass allocation ratio. These traits could serve as valuable proxies for early-stage screening of saline-alkaline-tolerant soybean genotypes.

The findings from this study offer promising avenues for cultivating soybean in saline-alkaline soils, as well as for breeding high-yielding, stress-tolerant soybean hybrids. These identified tolerant genotypes could be key to developing more resilient soybean varieties capable of thriving in challenging growing conditions.

This research was supported by NNSFC, ARC, UWA and Northwest A&F University, China.

Barley plants cultivated under different phosphorus and water conditions.

Phosphorus and waterlogging stress in barley: impact on growth and tolerance mechanisms

Project team: Dr Yinglong Chen[1] (Project leader; yinglong.chen@uwa.edu.au), Professor Sergey Shabala[1], Weida Jiang[1].

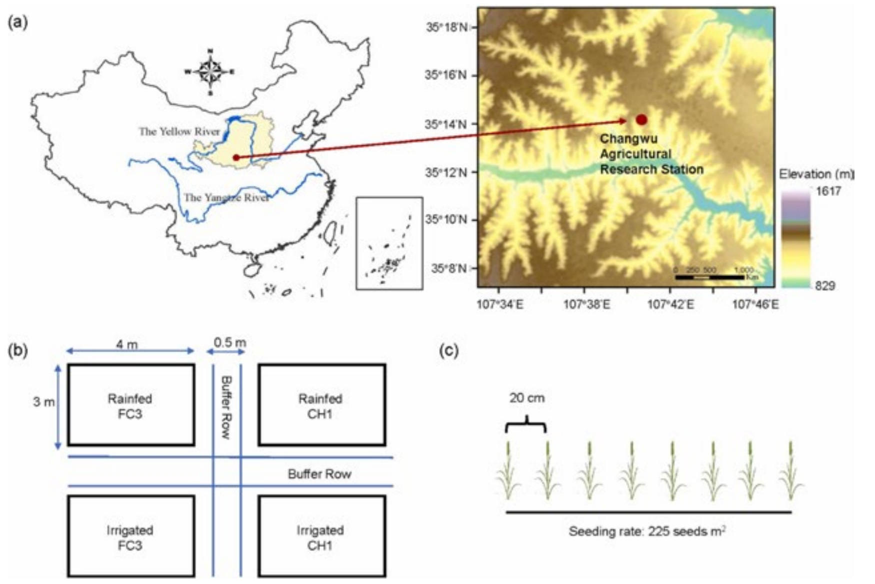
Collaborating organisations: [1]UWA.

Phosphorus (P) is a vital nutrient for plants, playing a critical role in photosynthesis, energy storage and transfer, cell division, enlargement, and genetic information transfer. Waterlogging significantly affects plant health and agricultural productivity, especially in the context of climate change and shifting rainfall patterns. It may also influence soil properties including P availability. This study aims to evaluate genotypic variation in response to waterlogging stress and P availability in 21 barley (*Hordeum vulgare*) genotypes.

Barley plants grew in pots filled with sandy soil amended with low or high P under normal water or flooding conditions till the tillering stage. Results showed that root characteristics were positively correlated with P availability and negatively affected by waterlogging stress. Notably, genotypes such as TX9425, Yerong, Franklin, and Sahara exhibited waterlogging tolerance. Genotypes Sahara and Clipper showed enhanced performance under low P conditions. This study revealed the relationship between root morphology, P absorption, and waterlogging tolerance in barley. Further research will aim to identify molecular mechanisms underlying root responses to low P stress and waterlogging stress.

This study highlights the complex interaction between P availability and waterlogging stress in barley. The findings can inform breeding programs aimed at developing barley varieties that are more resilient to waterlogging, particularly in regions where climate change is expected to alter rainfall patterns and P dynamics.

This research was supported by ARC and UWA.



Location of Changwu Agricultural Research Station of Chinese Academy of Sciences (a), layout of the experimental field for one replication (b), sowing arrangement and seeding rate (c) during 2015–2016 and 2016–2017.

Root traits and drought resilience: how modern wheat cultivars outperform in challenging conditions

Project team: Dr Yinglong Chen[1] (Project leader; yinglong.chen@uwa.edu.au), Dr Yan Fang[2], Dr Jun Wang[2], Ranran Zhang[2], Fengxian Li[2], Dr Liyan Liang[3], Shuo Liu[1], Professor Bingcheng Xu[2].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]Gansu Agricultural University, China.

As climate change leads to more frequent and intense droughts, understanding how wheat genotypes respond to drought stress has become crucial for improving yield stability and production. Our recent study aimed to examine how different wheat cultivars, representing old and modern varieties, perform under early and terminal drought conditions. This research is key to enhancing wheat productivity in the face of increasingly erratic rainfall patterns.

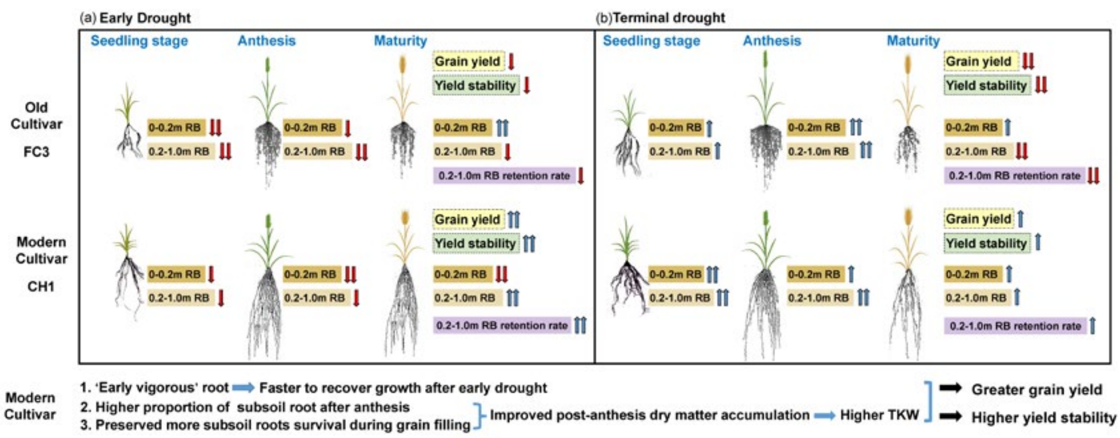
Over two years, a field trial and pot experiment were conducted to assess root growth and grain yield in two wheat cultivars: FC3, a 1960s variety, and CH1, a modern cultivar from the 2010s. These experiments were carried out under both rainfed and irrigated conditions. The rainfed wheat faced terminal drought in the 2015-2016 growing season and early drought in 2016-2017. Plants in the pot experiment were subjected to terminal drought, early drought, or well-watered conditions.

The results showed that modern cultivar CH1 outperformed FC3 in grain yield in both the field and pot experiments. While both cultivars experienced yield reductions due to drought, FC3 suffered a greater decrease in yield, especially under early drought conditions. Notably, CH1 demonstrated higher yield stability, with a smaller reduction in grain yield during early drought periods. One key difference between the cultivars was their root growth. CH1 exhibited more robust root biomass during the early growth stages compared to FC3. At anthesis (the flowering stage), CH1 had significantly lower root biomass and root length density in the topsoil layer (0–0.2 m) but had more root growth in the subsoil layer (0.2–1.0 m). Furthermore, at maturity, CH1 retained a higher proportion of root biomass in the subsoil, especially under early drought conditions. In the field, CH1 retained 80.2% of its subsoil root biomass, while in the pot experiment, this figure rose to 93.9%. Interestingly, both cultivars had similar seasonal water usage, but CH1 used water more efficiently. It reduced water consumption before anthesis, then increased its water uptake after anthesis, which contributed to its higher yield under drought stress. This strategy of deep-rooted growth and efficient water use helped CH1 maintain a higher thousand kernel weight, a key factor in its yield advantage.

In conclusion, the study highlights the importance of vigorous early root growth and the ability to retain root biomass in deeper soil layers during drought periods. Modern cultivars like CH1 have developed these traits, which improve water use efficiency, photosynthesis, and dry matter accumulation, ultimately leading to higher yields and greater yield stability under both early and terminal drought conditions.

These findings are crucial for breeding and cultivating wheat varieties that can thrive in increasingly unpredictable growing environments, ensuring stable food production in the face of climate change.

This research was supported by NNSFC, Chinese Universities Scientific Fund, China Postdoctoral Science Foundation Funded Project and ARC.



A model of grain yield, yield stability and root growth traits in three growth stages in an old cultivar FC3 and a modern cultivar CH1 of winter wheat under early drought (a) and terminal drought (b) conditions.

Genotypic variability in root morphological traits in canola at the seedling stage

Project team: Dr Yinglong Chen[1] (Project leader; yinglong.chen@uwa.edu.au), Dr Sheng Chen[1], Andrew Chen[1], Yongkang Peng[1].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]Gansu Agricultural University, China.

Canola (*Brassica napus* L.) is a key global oilseed crop, but its sustainable production is increasingly threatened by climate change. Enhancing root traits through breeding offers a pathway to improve soil nutrient uptake, water-use efficiency, and resilience to environmental stresses.

This study assessed 25 root morphological traits and 2 shoot traits across 173 canola genotypes using a semi-hydroponic phenotyping platform under controlled conditions. Substantial genotypic variation was observed in most root traits. Nineteen traits with a coefficient of variation greater than 0.3 were selected for detailed analysis. Principal component analysis revealed five components with eigenvalues greater than 1, collectively explaining 87.9% of the total variance. Hierarchical cluster analysis grouped the genotypes into five distinct clusters based on their root trait profiles.

These findings highlight significant genotypic diversity in root morphology, providing a valuable resource for identifying molecular markers and genes linked to root architecture. This study lays a solid foundation for the genetic improvement of canola, aiming to enhance resource-use efficiency and adaptability to climate-induced stresses such as drought and heat.

This research was supported by GRDC and ARC.

Canola cropping farm in Northam, Western Australia.

Enhancing phosphorus-use efficiency in wheat by reducing seed phosphorus and phytate concentrations

Project team: Hackett Professor Kadambot H.M. Siddique[1] (Project leader; kadambot.siddique@uwa.edu.au), Emeritus Professor Hans Lambers[1], Senior Fellow Research Jiayin Pang[1].

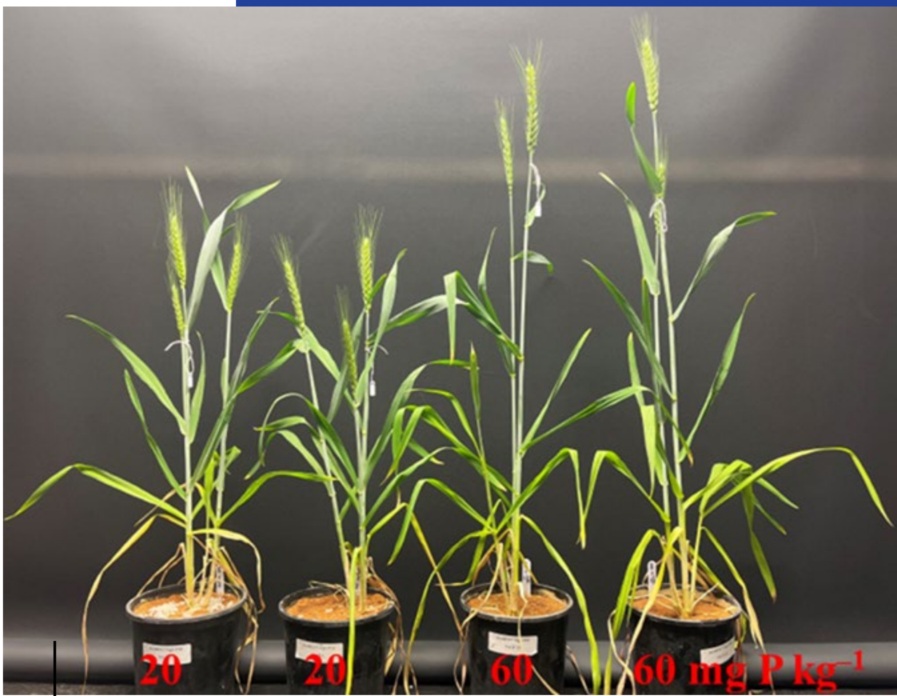
Collaborating organisations: [1]UWA.

Phosphorus (P) availability in soil is a major limiting factor for global crop productivity. Excessive P accumulation in seeds, primarily stored as phytate, can lead to resource waste and environmental pollution. Wheat, a staple crop worldwide, plays a critical role in human and animal nutrition. Therefore, reducing seed phytate concentrations is crucial for improving nutrient availability and fertiliser-use efficiency.

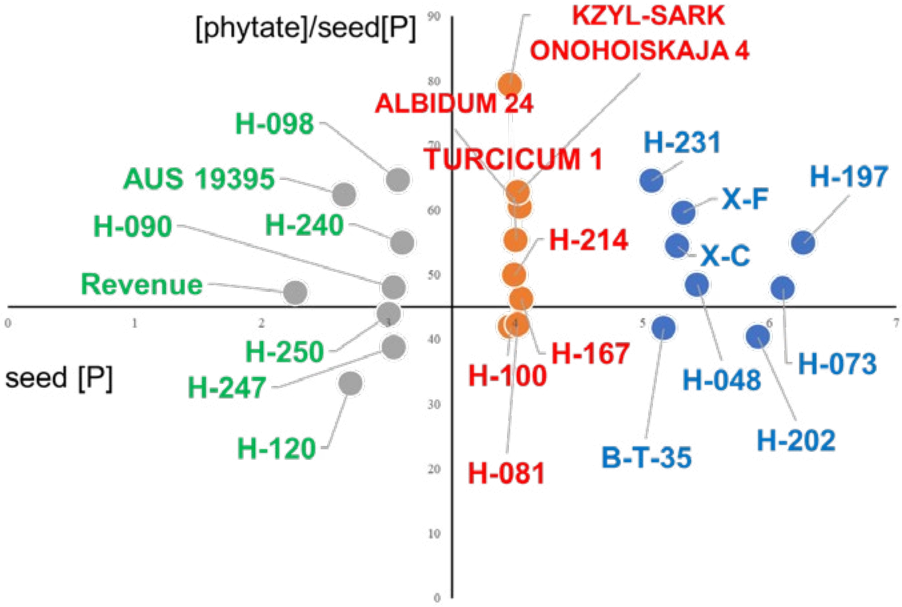
This project aims to enhance wheat P-use efficiency (PUE) by reducing seed P and phytate concentrations. The study evaluated 24 wheat (Triticum aestivum L.) genotypes to identify genotypic variation in P remobilisation and PUE.

Assessed seed P, phytate, and other nutrients (Zn, Fe, Ca, Cu, Mg, Mn) in 24 wheat genotypes under two P levels and analysed their correlations.

This research is supported by HDR, that will provide $1500 for doctoral students annually for three years. Travel funding supported by GRS will be applied for travel relevant to research work, including conferences or travel to gather research data. Additional budget will be sourced from supervisors' ARC Linkage Project.



Wheat accessions screening work.



Example of one wheat accession grown under two P levels.

Enhancing wheat yield and nitrogen use efficiency in the Huang-Huai-Hai region of China: Insights from root biomass and nitrogen application responses

Project team: Professor Xiaoliang Qin[2] (Project leader; xiaoliangqin2006@163.com), Xiaoxia Wen[2], Tiantian Huang[2], Maoxue Zhang[2], Pengfei Dang[2], Wen Wang[2], Miaomiao Zhang[2], Yanyu Pan[2], Xiaoping Chen[2], Yuncheng Liao[2], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China.

Wheat yield and nitrogen use efficiency (NUE) have improved simultaneously with the genetic development of wheat varieties. However, wheat selection is carried out routinely in N-rich field conditions, with breeding progress limited under low soil available nitrogen.

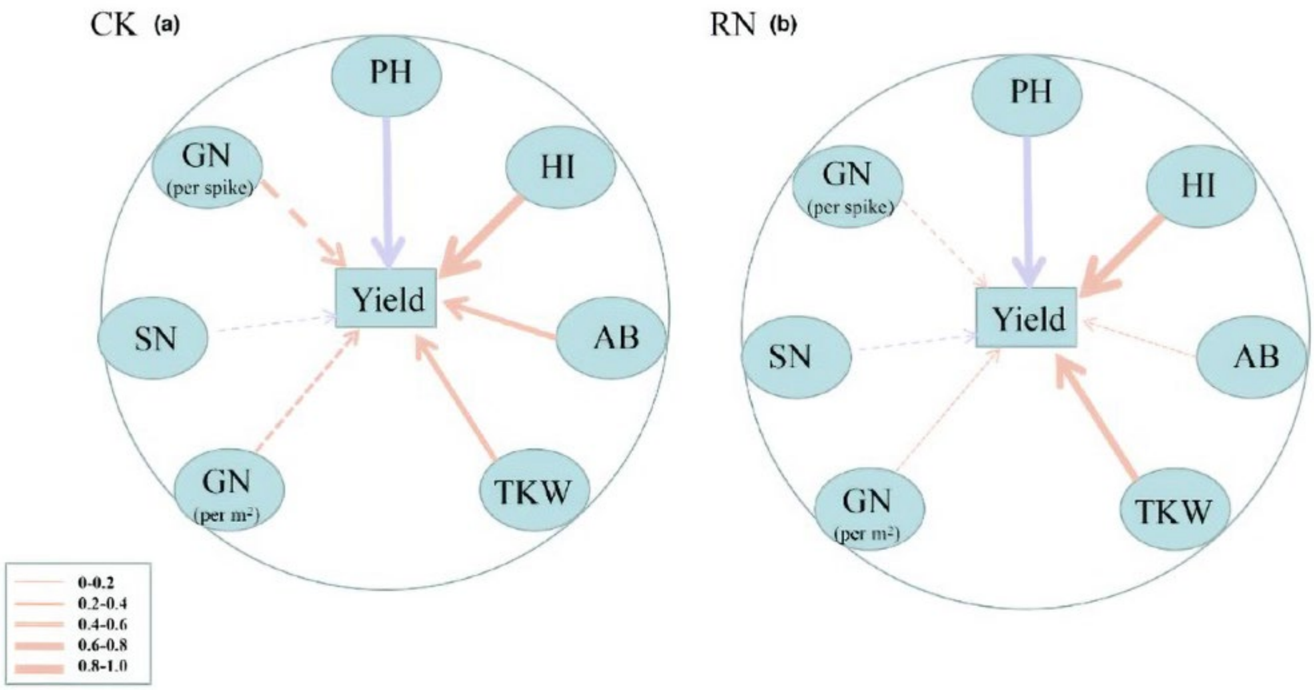
This study performed a 2-year field investigation using eight milestone winter wheat varieties released between 1947 and 2017 in the Huang-Huai-Hai region of China with two N applications—normal (CK; 220 kg N ha^{-1}) and reduced (RN; 110 kg N ha^{-1})—in Shaanxi, China, to examine changes in wheat yield, NUE, water use efficiency (WUE) and root biomass.

Findings revealed average annual yield increases of 49.615 kg ha^{-1} and 36.905 kg ha^{-1} under CK and RN, respectively. Notably, the NUE trend mirrored yield, increasing with the release year of wheat varieties, with average annual increases in NUE of 0.192 and 0.336 kg kg^{-1} under CK and RN, respectively. In the RN treatment, N uptake efficiency (UPE) increased with year of release, while N utilization efficiency (UTE) had no significant relationship. In the CK treatment, UTE increased with year of release, while UPE had no significant relationship.

Across the 2-year experiment, surface root biomass (0–20 cm layer) increased with year of release under CK but had no relationship under RN, while deep root biomass (20–200 cm layer) decreased with year of release under CK and increased under RN. The roots of modern wheat varieties responded better to soil nitrogen levels and produced higher yields, NUE and WUE than earlier varieties by adjusting root biomass distribution in soil.

These findings underscore the adaptability and resilience of modern wheat varieties, highlighting their potential to address the evolving challenges presented by changing climate patterns and shifting agricultural practices in the coming years.

This research is supported by NNSFC.



Correlation analysis between yield and plant height (PH), grain number per spike (GN per spike), grain number per m 2 (GN perm 2), spike number per m2 (SN), thousand kernel weight (TKW), aboveground biomass (AB) and harvest index (HI) at maturity under (a) normalN (CK) and (b) reduced N (RN) in 2019 and 2020. Dotted line indicates $p > 0.05$ and solid lines indicate $p < 0.05$. Orange arrows are positivecorrelations and purple arrows are negative correlations.

Modification of plant sterols to protect against insect pests

Leaves of transgenic canola lines confer insect resistance.

Project team: Professor Jacqueline Batley[1] (Project leader; jacqueline.batley@uwa.edu.au), Dr Jing Li[1], Miguel Vaz Pereira[1], Jelena Um[1,3].

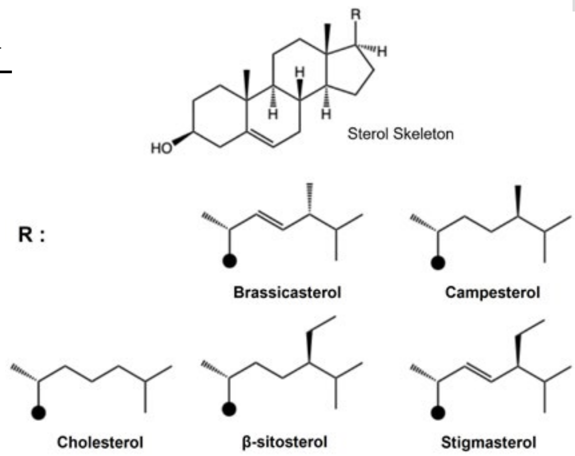
Collaborating organisations: [1]UWA; [2]Murdoch University; [3]Nagoya University, Japan.

Insect pests cause enormous crop losses and continue to develop resistance to chemical and biological control measures. There has been an urgent need to develop alternative control measures to protect crops from insect pests.

Herbivorous insect pests reply on ingesting essential phytosterols from the host to support their growth and development. Phytosterols utilised by insect pests from plants need to meet strict structural requirements in order to be converted to cholesterol, a precursor of insect moulting hormone, therefore some phytosterols are not suitable for the development and reproduction of insects. This important pest-host interaction provides a crucial concept from which a novel insect pest control strategy can be developed.

The goals of this study are to modify plants to produce non-utilizable sterols which will not support insect growth and reproduction but will still function normally in plants. Canola lines with novel sterol composition conferring insect resistance will be generated and tested for insect resistance.

Sterol Structures.



Several approaches have been employed to obtain canola lines with modified sterol composition for insect resistance. This includes the identification and selection of novel sterol synthesis genes in canola sterol biosynthesis pathways. Two of these genes have been transformed to canola plants, resulting in canola lines with non-utilizable sterols. Insect feeding data has shown these canola lines have negative effects on insect growth and development. The insects raised on canola lines have reduced body weight and decreased survival rate. The insects tested are cutworm, aphid and diamondback month.

In addition to these efforts, further progress is being made through the identification and selection of 50 mutants in sterol biosynthesis genes from a TILLING population of Brassica rapa. 19 annotated sterol genes have been selected from B. rapa collection. This collection is being screened for novel sterol profiles and lines of interest will be selected for insect feeding studies. Furthermore, target genes for generating canola CRISPR lines for insect resistance have also been identified, and CRISPR experiments are currently in progress.

Technology developed from this research will contribute to agricultural industry with greener, sustainable tool to combat insect pests.

This research is supported by GRDC and ARC discovery.

Canola plants at flowering stage in 2024 canola drought experiment at UWA showing the 1-meter-tall tubes and the portable weighing system.

Development of new genetic sources for canola heat tolerance

Project team: Dr Sheng Chen[1] (Project leader; sheng.chen@uwa.edu.au), Professor Wallace Cowling[1], Hackett Professor Kadambot Siddique[1], Dr Aldrin Cantila[1], John Quealy[1], Xiaojie Hu[1], Dr Rajneet Uppal[2], Dr Suman Rakshit[3]

Collaborating organisations: 1UWA; [2]NSW DPIRD; [3]AAGI.

In 2024, GRDC funded the phase 2 research aiming to develop new genetic sources for canola heat tolerance (UWA2404-011RTX). UWA co-ordinates this project, which is a collaboration between UWA, NSW DPIRD and AAGI.

In previous years, a protocol for heat stress tolerance in canola based on a single heat stress event at first flower was developed and it was useful to identify heat-tolerant germplasm and heat-sensitive germplasm, but many genotypes fully recovered on the side branches of the plants and some even on the main stem. In 2024, single and double heat stress events during flowering to separate two potential measures of heat tolerance was explored: (i) tolerance of the heat stress events, and (ii) recovery from the heat stress events. The aim of this experiment is to fine-tune the phenotyping protocol for screening of heat tolerance and to deliver the canola breeders a reproducible and reliable protocol for heat tolerance phenotyping at single plant level and at field plot level.

At UWA's Field station at Shenton Park, 15 canola genotypes were tested in the screenhouse. From early flowering stage, plants were subjected to control treatment (No heat stress, T0) and four different types of heat stresses: 7 days of heat stress from 1st open flower (T1), 7 days of heat stress from 7 days after 1st open flower (T2), 14 days of heat stress from 1st open flower (T3), and long heat stress from 1st open flower to maturity (T4). A total of 38 traits were measured on different sections of main stems and whole plants. The percentage change and stress tolerance index were calculated to assess the heat tolerance to the above four different types of heat stresses at single plant level.

At Wagga Wagga Agriculture Institute, 8 canola genotypes were tested at field plot level. By using the portable heat chambers, plants were subjected to four different treatments: T1, Control; T2, 4 days of heat stress at 25% flowering of the plot; T3, 4 days of heat stress at 100% flowering of the plot; T4, combined T2+T3. Similar measurement of traits and evaluation of heat stress tolerance were applied at field plot level.

In the field, crops are simultaneously exposed to an array of environmental stressors, which can substantially impact yield. Heat and drought stress is increasing in the growing season in Australia due to climate change. Warm winters and spring heat waves results in more frequent drought and heat stress confounding. In previous years, some lines with good heat stress tolerance were obtained. In 2024, a drought experiment was conducted at UWA's Plant Growth Facility in Crawley using 168 PVC tubes with 150mm in diameter and 1000mm in length (Figure 1). 21 canola genotypes were selected from the heat tolerance trials in previous years. The weight of each tube was measured regularly to ensure the soil water content (SWC) above 70% for control treatment, and the water loss rate was used to predict the number of days required for each tube to reach certain SWC as drought stress. The BBCH growth stages of canola plants, particularly those under drought conditions, were carefully monitored. At the BBCH60, i.e. the first open flower, the SWC of each drought-treated tube was estimated, and tags were applied at SWC between 42-53%, between 53-65%, and above 65%. Biomass, seed yield and harvest index were measured. Percentage change and stress tolerance index were calculated to indicate the stress tolerance level. Some physiological and biochemical parameters, such as pollen viability, leaf gas exchange, chlorophyll A fluorescence, superoxide dismutases (SODs) and membrane stability index (MSI), were also measured to explore the mechanism of drought tolerance at physiological and biochemical levels.

In 2024, RNAseq and proteomics approaches were used to explore the molecular mechanism of canola heat tolerance.

In 2024, UWA researchers also established 5 F2 segregation populations for canola heat tolerance. One F3 population were achieved so far and F5/F6 will be further achieved in the next 12 months.

This research is supported by GRDC (project UWA2404-011RTX), UWA and NSW DPIRD.

Sheep herd in UWA Farm Ridgefield.
Credit: Dr Kelsey Pool.

2

Sustainable Animal Production Systems

Research undertaken in the Sustainable Animal Production Systems theme has contributed to the nexus between crop/pasture and livestock production, conducted in close cooperation with other national and international Research, Development, Extension and Adoption partners.

This theme encompasses the sustainable contribution of livestock industries to global food supply. The focus is on resolving five key problems. These are:
1) The consumption of human food by livestock,
2) Livestock species and genotypes that are poorly adapted to the local environment,
3) Poor animal health and welfare resulting in sub-optimal productivity,
4) Provision of adequate animal nutrition, and
5) The environmental footprint.

Mixed crop-pasture systems in the agricultural region of 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 if they are to continue to support animal-production systems. UWA has a current focus on development of phosphorus efficient pastures that can maintain productivity on lower soil phosphorus levels. Within the system, the interaction of pasture and crop is critical to the management of weeds, including herbicide resistant weeds, because within the pasture phase, offers a clear pathway that can supplement options to improve sustainability of cropping. Aspects of efficient nutrition use and disease control also show promise to alleviate issues that are problematic in the cropping phase.

Theme Leaders

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Group of Animal on Green Grass Field.

Fat deposition and partitioning for meat production in cattle and sheep

Project team: Adjunct Associate Professor Shimin Liu[1](Project leader; shimin.liu@uwa.edu.au), Emeritus Professor Graeme B. Martin[1], Yanyan Yang[2], Hailing Luo[3], Wenjie Pang[4].

Collaborating organisations: [1]UWA; [2]Institute of Animal Husbandry of Inner Mongolia Academy of Agricultural and Animal Husbandry Sciences, China; [3]College of Animal Science and Technology of China Agricultural University, China; [4]Resonance Health, Australia.

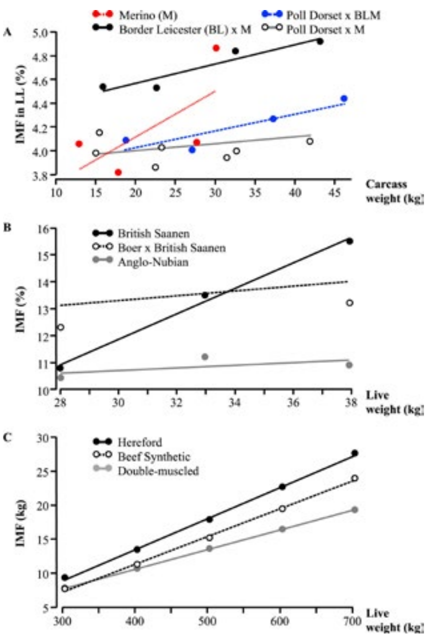
This study addresses the challenge of improving intramuscular fat (IMF) in beef and sheep meat, a key factor in meat quality, without increasing overall fatness. Both genetic selection and dietary strategies can enhance IMF, but these approaches often lead to undesirable increases in subcutaneous (SCF) and visceral (VF) fat, which reduces carcass quality and increases feed costs. The paper explores the complexities of fat partitioning, noting that while IMF accretion rates are slower than SCF and VF, selective breeding for higher IMF or increased dietary energy can elevate overall fatness.

The genetic correlation between IMF, SCF, and VF varies across genotypes, presenting a challenge for effective selection. Although IMF is heritable, most breeds of cattle and sheep naturally produce low IMF levels, and improvement through genetic selection is slow. Moreover, precise selection requires accurate measurement of both IMF and SCF, particularly in live animals, to identify individuals with desirable fat profiles at an early age. This would help shorten the generation interval and accelerate genetic gains.

Current technologies allow for direct measurement of IMF in progeny or siblings but are limited in their ability to assess IMF and SCF simultaneously in live animals. Radiation-based techniques are available but are not yet practical for large-scale use in the field. The paper suggests that advances in molecular genetics, particularly in understanding genes related to adipogenesis and lipogenesis, could further aid in selecting for optimal fat deposition patterns.

In conclusion, the study emphasises the need for breed-specific selection strategies and highlights the importance of developing new technologies for accurate, live-animal measurements. By overcoming these challenges, genetic selection for improved IMF without excessive fat deposition could be achieved, benefiting both producers and consumers.

This research is supported by the UWA.



The relationships between intramuscular fat (IMF) and carcass weight or liveweight in various breeds of sheep, goats and cattle. Mean IMF is plotted against carcass weight or animal body weight, with data taken from publications as follows. (A) The IMF (%) in longissimus thoracis et lumborum (LL) muscle was determined by near-infrared spectroscopy and carcass fat content was determined by dual energy X-ray absorptiometry in sheep slaughtered at 4, 8, 14, and 22 months of ages (McPhee et al., 2008). (B) Dissected intermuscular fat (IntMF, %) in carcasses of three goat breeds slaughtered at 18, 33, and 38 kg liveweight (Gibb et al., 1993). (C) Dissected IntMF (kg) in three cattle breeds, recalculated from the means of the allometric growth coefficients of the regression of IntMF (kg) against liveweight (Shahin and Berg, 1985).

Soil, plant, and microorganism interactions drive secondary succession in restoration of alpine grassland

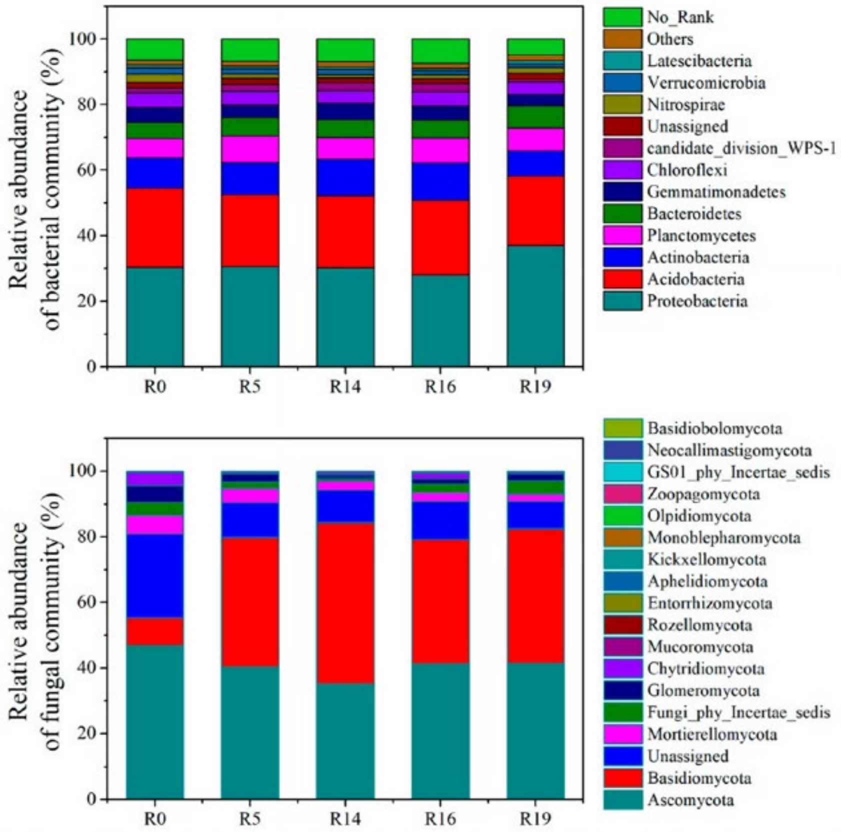
Project team: Professor Yanjie Gu[2] (Project leader; guyanjie@qhu.edu.cn), Hackett Professor Kadambot H.M. Siddique[1], Chenglong Han[2], Defei Liang[2], Weidi Zhou[2], Qiuyun Xu[2], Mingxue Xiang[2].

Collaborating organisations: [1]UWA; [2]Qinghai University, China.

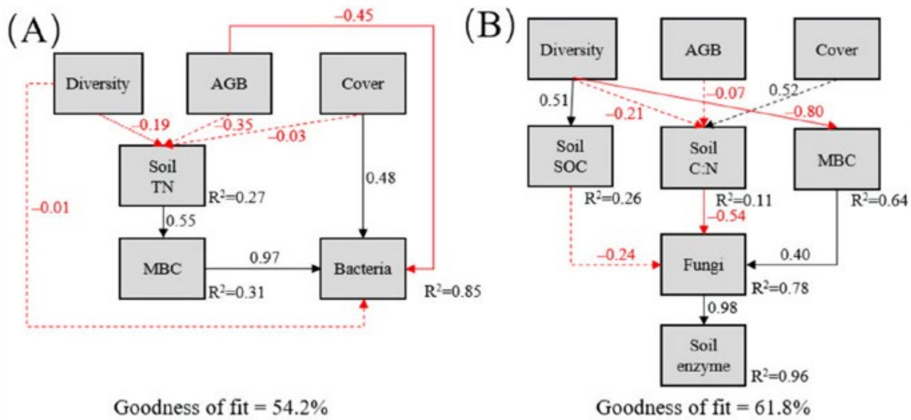
This study examines the secondary succession of plant and soil microbial communities during the restoration of alpine grasslands on the Qinghai-Tibet Plateau in China. The research focuses on five grasslands at different stages of recovery (0, 5, 14, 16, and 19 years) to explore how soil properties, plant communities, and microbial populations evolve over time. Using high-throughput sequencing, enzymatic activity assessments, and biomass analyses, the study identifies distinct patterns in plant and microbial succession across the chronosequence.

Results show that soil organic carbon, total phosphorus, and NH^{4+}-N content increased as the grasslands recovered, alongside rising soil microbial biomass, enzymatic activities, and microbial diversity. The changes in microbial communities were closely linked to plant biomass, cover, and diversity, with higher plant diversity promoting greater microbial richness and activity. Notably, plant and fungal succession occurred in parallel, suggesting a strong interplay between aboveground and belowground processes.

Bacterial succession was primarily influenced by plant biomass and soil nitrogen content, while fungal succession was more sensitive to changes in the soil C:N ratio. The study found that the structure of the microbial community was also affected by variations in the activity of soil enzymes, particularly phosphatase, which plays a crucial role in nutrient cycling. These findings underscore the importance of plant



Relative abundance of soil bacterial and fungal communities with secondary succession time at the phylum level. R0: highly degraded grassland; R5: recovery time of 5 years; R14: recovery time of 14 years; R16: recovery time of 16 years; R19: recovery time of 19 years.



Partial least squares path models (PLS-PM) illustrating the relationships among plant communities, soil properties, and bacteria (A) and fungi (B). Red and black arrows indicate negative and positive causality flows, respectively. Numbers above lines indicate normalized path coefficients. Dotted red lines indicate non-significant path relationships. R2 values beside the latent variables denote coefficients of determination.

biomass, cover, and diversity in shaping microbial communities, influencing soil nutrient dynamics, and modifying soil microclimates.

The study contributes valuable insights into the intricate relationships between plants and soil microbes during grassland restoration. It highlights the need for strategies that enhance plant recovery, such as alternating grazing, to support both plant and microbial succession. The research advances our understanding of ecosystem functioning in alpine grassland, offering guidance to improve restoration efforts in degraded alpine regions and other similar ecosystems.

This research is supported by the Natural Sciences Foundation of Qinghai Province and NNSFC.

Herd of Merino Sheep grazing in a paddock.

Greenbottle, Blowfly, Insect image.

Investigating the role of blowfly olfaction in flystrike in sheep

Project team: Emeritus Professor Graeme B. Martin[1] (Project leader; graeme.martin@uwa.edu.au), Guanjie Yan[2], Anthony C. Schlink[1], Adjunct Associate Professor Shimin Liu[1], Johan C. Greeff[1], Gavin R. Flematti[3].

Collaborating organisations: [1]UWA; [2]China-UK-NYNU-RRes Joint Laboratory of Insect Biology, Nanyang Normal University, China; [3]DPIRD.

Flystrike, caused by the larvae of the sheep blowfly, Lucilia cuprina, leads to significant losses in wool and meat production, costing the industry more than A$320 million annually. Common prevention methods, such as insecticides, crutching, and mulesing, have drawbacks, including the development of insecticide resistance and ethical concerns surrounding mulesing.

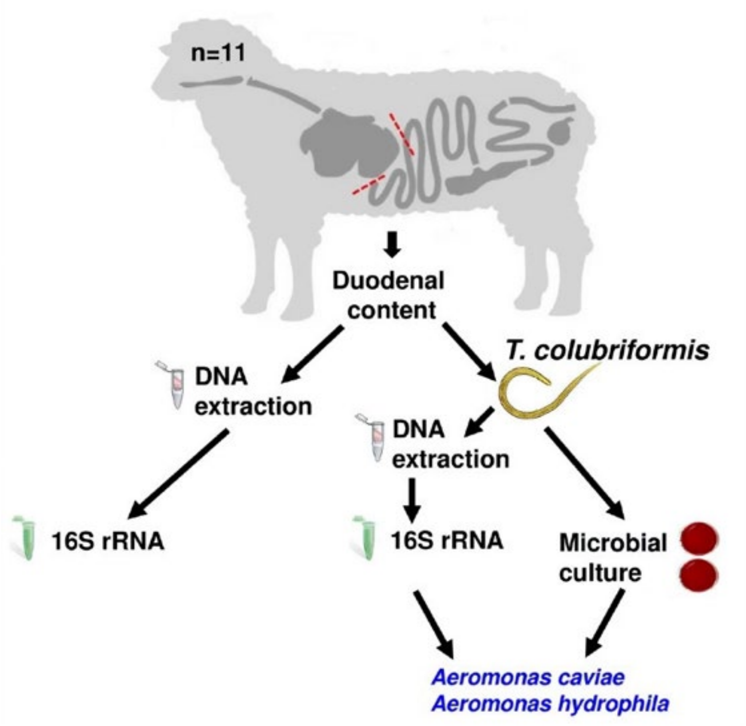
This study examines the challenge of preventing breech flystrike in Australian Merino sheep, a major concern for animal welfare and the wool industry.

Breeding for resistance to breech flystrike offers a promising alternative, but the trait is difficult and expensive to measure in extensive production systems. Research has focused on identifying indirect traits that could be incorporated into breeding programs, such as skin wrinkles, fleece rot, dags, and urine stains. However, these factors explain only about 40% of the variation in susceptibility to flystrike, indicating that other factors are involved.

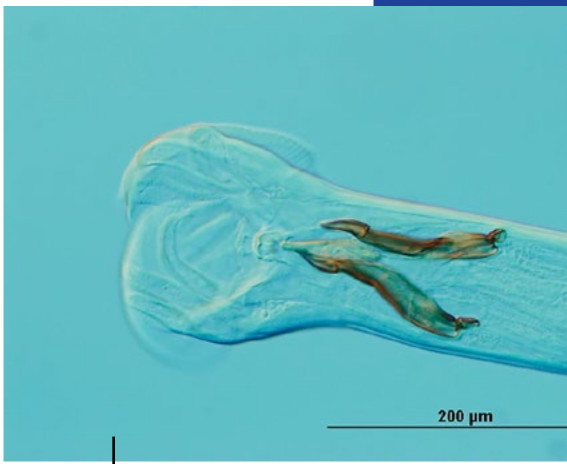
The study shifts focus to insect olfaction, particularly the role of odour in the detection of potential hosts by Lucilia cuprina. Using gas chromatography-mass spectrometry and electroantennographic detection, researchers identified several odouriferous compounds in Merino wool, including octanal, nonanal, and dimethyl trisulfide, which attract gravid blowflies. These compounds are also heritable, suggesting that they may serve as useful traits in breeding programs for flystrike resistance.

By understanding the semio-chemical interactions between Lucilia cuprina and Merino sheep, the study proposes that breeding for specific odour profiles could offer an effective, sustainable solution to flystrike. Advances in this area could save the Australian Merino industry up to A$200 million annually while improving the industry's ethical image globally.

This research is supported by UWA, AWI and DPIRD. During his PhD studies in Australia, GJY was a recipient of a Postgraduate Scholarship from the CSC.



Experimental design, including the collection of duodenal content, DNA extraction, 16S rRNA analyses, microbial culture, and bacterial isolation from T. Colubriformis.



The caudal region of T. colubriformis collected from the duodenal content. The typical male spicules of the adult nematode are shown.

Revealing the associated microflora hosted by the globally significant parasite *Trichostrongylus colubriformis*

Project team: Erwin A. Paz[1] (Project leader; Erwin A. Paz), Eng Guan Chua[1], Dieter G. Palmer[2], Johan C. Greeff[1,2], Emeritus Professor Graeme B. Martin[1], Adjunct Associate Professor Shimin Liu[1], Carolina Cheuquemán[3], Shamshad Ul Hassan[1], Chin Yen Tay[1].

Collaborating organisations: [1]UWA; [2]DPIRD; [3]Universidad del Alba, Chile.

This study investigates the intestinal microbiome of *Trichostrongylus colubriformis*, a parasitic helminth that affects small ruminants and causes significant economic losses in the livestock industry. The research compares the microbiome of the helminth, collected from the duodenum of sheep, with that of its host to understand potential influences on the parasite's survival. Using 16S rRNA differential abundance analysis, the study identified *Mycoplasmoides* and *Stenotrophomonas* as abundant in the parasite but absent in the sheep's duodenal microbiome.

Two bacteria, *Aeromonas caviae* and *Aeromonas hydrophila*, were also isolated from the parasite, with genome analysis revealing differences in the profile of antimicrobial resistance (AMR). These findings suggest that the helminth carries a specific bacterial community that may support its long-term survival in the host's digestive system.

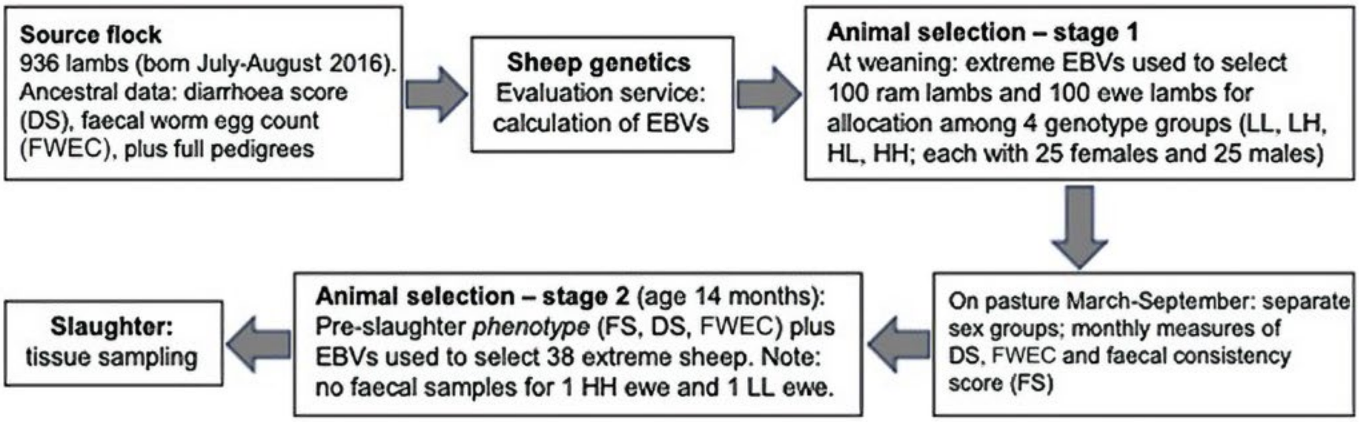
The research further examines the complex interplay between parasitic helminths and their host's microbiome, focusing on the microbial composition of both *T. colubriformis* and its host. The results showed significant differences in bacterial species richness and composition between the parasite and the host, with unique ecological factors contributing to these differences. The identified bacteria, such as *Mycoplasmoides* and *Stenotrophomonas*, may play a role in the parasite's colonisation and survival within the host. These findings are consistent with previous studies on other gastrointestinal nematodes, suggesting a potential symbiotic relationship between the parasite and its microbiota.

Additionally, genomic analysis of strains of *Aeromonas caviae* and *Aeromonas hydrophila* revealed variations in their AMR gene profiles, which could inform future control strategies. The presence of these bacteria, along with other identified genera, underscores the potential to develop novel helminth control strategies based on microbial interactions.

Overall, this study highlights the importance of understanding the microbiome of both the host and parasite, opening new avenues to manage parasitic infections in livestock.

This research is supported by WAMMCO Katanning abattoir.

Relationships among gastrointestinal mucosal densities of mast cells and eosinophils, helminth infection, and diarrhoea in sheep



Schema illustrating the experimental protocol, including the two-stage process of selection of experimental animals.

Project team: Emeritus Professor Graeme B. Martin[1] (Project leader; graeme.martin@uwa.edu.au), Xiaoyan Niu[3], Adjunct Associate Professor Shimin Liu[1], Dieter G Palmer[2], Johan Greeff[1,2]

Collaborating organisations: [1]UWA; [2]DPIRD; [3]Shanxi Agricultural University, China.

This study examines the relationship between the distribution of immune cells in the gastrointestinal tract and resistance to helminths and diarrhoea in sheep. Diarrhoea linked to helminth resistance is a major challenge in sheep production, with significant economic implications due to productivity losses, flystrike, and the risk of carcass contamination. The research investigates how eosinophils and mast cells influence both parasite resistance and hypersensitivity diarrhoea.

Lambs with extreme breeding values for diarrhoea score and faecal worm egg count (FWEC) were monitored from weaning until 14 months of age under typical farm conditions. Those with extreme phenotypic values were selected for post-mortem analysis, where eosinophil and mast cell densities were recorded across the abomasum, duodenum, ileum, jejunum, caecum, and colon. The study found a strong negative correlation between eosinophil density and helminth burden in the jejunum and abomasum ($P < 0.05$). Similarly, higher mast cell density in the abomasum was linked to lower FWEC and helminth counts, particularly of *Teladorsagia circumcincta*. However, while these immune responses reduced the parasite burden, they also contributed to hypersensitivity diarrhoea.

The findings suggest that immune-driven responses in the gastrointestinal tract play a dual role: improving resistance to internal parasites while increasing susceptibility to diarrhoea. This aligns with previous studies on hypersensitivity diarrhoea, where inflammatory mediators released by mast cells and eosinophils caused intestinal hypermotility. The study highlights the trade-off in breeding for helminth resistance, as genetically resistant sheep may be predisposed to diarrhoea, a condition exacerbated by hypersensitivity to larval-stage helminths.

Understanding the immune mechanisms behind helminth resistance and hypersensitivity diarrhoea could inform selective breeding strategies to balance resistance and welfare outcomes. These findings provide valuable insights for sustainable parasite control in sheep farming.

This research was supported by the Shanxi Scholarship Council of China, and DPIRD.

Flock of sheep.

Effects of yak rumen anaerobic fungus Orpinomyces sp. YF3 fermented on in vitro wheat straw and microbial communities in dairy goat rumen fluid, with and without fungal flora

Project team: Yangchun Cao[2] (Project leader; caoyangchun@126.com), Xueer Du[2], Linlin Zhou[2], Yong Li[2], Fan Zhang[2], Lamei Wang[2], Junhu Yao[2], Xinghua Chen[3], Adjunct Associate Professor Shimin Liu[1].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]Beth Israel Deaconess Medical Center, Harvard Medical School, USA.

This study investigated the impact of an anaerobic fungus Orpinomyces sp. YF3 from the yak rumen on rumen fermentation and microbiota when introduced to goat rumen fluid, both with and without the existing fungal flora. Using a 2×2 factorial design, four treatment groups were established: control (C), yak fungus group (CF), goat fungi eliminated group (CA), and goat fungi eliminated plus yak fungus group (CAF). Crushed wheat straw was used as the substrate, and cycloheximide was applied to eradicate microorganisms from the goat rumen.

The results showed that supplementation with Orpinomyces sp. YF3 (CF and CAF groups) significantly increased ammonia nitrogen by 70%, total volatile fatty acids (VFA) by 53%, as well as concentrations of acetate, isobutyrate, and valerate. The ratio of acetate to propionate also increased, while the propionate proportion declined by 13%, accompanied by a reduction in butyrate. High-throughput sequencing revealed that the addition of yak fungus was associated with a notable increase in the relative abundance of several bacterial groups, including Bacteroidota, Synergistota, and Desulfobacterota, and a decrease in Fibrobacterota and Proteobacteria. These bacterial groups were positively correlated with higher carboxymethyl cellulase and avicelase activity, increased VFA concentrations, and a higher acetate proportion, while being negatively correlated with propionate production.

Picture of a goat.

The findings suggest that the introduction of Orpinomyces sp. YF3 to the rumen fluid of goats promotes fibre degradation, increases acetate production, and enhances cellulose breakdown. The intervention presents a promising strategy to improve roughage utilization in ruminant animals, supporting more efficient digestion of the components of fibrous feed.

This research is supported by Ningxia Key Project of R&D Plan, National Key Research and Development Program China and Shaanxi Science Fund for Distinguished Young Scholars.

Effects of reduced levels of organic trace minerals in proteinate forms and selenium yeast in the mineral mix on lactation performance, milk fatty acid composition, nutrient digestibility, and antioxidant status in dairy goats

Project team: Pin Wang[2] (Project leader; wangping@nwafu.edu.cn), Adjunct Associate Professor Shimin Liu[1], Yongxi Song[2], Yunan Weng[2], Muhammad Usman[3], Juan J. Loor[3], Gang Lin[4], Qingyong Hu[2], Jun Luo[2].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]University of Illinois, USA; [4]Chinese Academy of Agricultural Sciences, China.

Dairy goat

This study assessed the effect of replacing inorganic trace minerals (ITM) with low levels of organic trace minerals (OTM) in proteinate forms and selenium yeast (Se-yeast) on the lactation performance, milk fatty acid (FA) composition, nutrient digestibility, and antioxidant status of prepartum and lactating Xinong Saanen dairy goats. A total of 40 goats were blocked by parity and body weight and randomly assigned to either ITM or OTM treatments from 4 weeks before parturition to 8 months of lactation. The goats received identical basal diets, differing only in their trace mineral supplements.

The ITM supplement included Fe, Cu, Zn, Mn, and Se in their inorganic forms, while the OTM supplement used proteinates of Fe, Cu, Zn, Mn at 50% of ITM levels and Se-yeast at 100% of ITM levels. The study measured various parameters at the first, second, fourth, and eighth months of lactation. Results indicated that goats in the OTM group had lower milk fat content ($P = 0.02$) but higher milk Se levels ($P = 0.03$) compared to those in the ITM group. Additionally, OTM supplementation altered the fatty acid composition of the milk, reducing the content of C6:0, C8:0, and C10:0 ($P < 0.05$), while increasing the content of odd- and branched-chain fatty acids such as C15:0 ($P = 0.01$).

The OTM group also exhibited improved total tract digestibility of dry matter ($P = 0.03$), crude protein ($P = 0.07$), ether extract ($P = 0.03$), and acid detergent fiber ($P = 0.05$). Furthermore, OTM goats showed reduced fecal excretion of Fe ($P = 0.01$), Cu ($P < 0.01$), and Zn ($P = 0.08$) compared to ITM goats. There was a trend towards higher serum glutathione peroxidase (GSH-Px) activity ($P = 0.09$) in the OTM group.

The study suggests that substituting lower levels of OTM for ITM can modify milk fat and fatty acid composition, without negatively affecting milk yield, nutrient digestibility, or antioxidant status in lactating dairy goats.

This research is supported by Special National Key R&D Plan of China, Key Research and Development Projects of Shaanxi Province, and Science and Technology Innovation Program of Shaanxi Province.

ZNE-AG CRC Project 1010 Northern Australia low methane feed base program – Phase 1 Discovery

Project team: Diane Ouwerkerk[2] (Project leader; diane.Ouwerkerk@daf.qld.gov.au), Steven Bray[2], Paul Stewart[2], Caroline Pettit[3], Gus Manatsa[4], Dr Zoey Durmic[1], Dr Sarah Meale[5], Dr Wesley Lawrence[6], Dr Beth Penrose[7].

Collaborating organisations: [1]UWA; [2]DPI, Queensland; [3]Northern Territory Department of Agriculture and Fisheries; [4]DPIRD; [5]The University of Queensland; [6]AgTech Consortium; [7]Charles Darwin University.

The Northern Australia low methane feedbase program is a national research collaboration that aims to identify and investigate Australian native forage plants that can reduce annual livestock enteric methane emissions by 20-40% or 8.2M tonnes of CO_2 equivalent avoided over 10 years.

This project, a 'discovery' phase of research, will collect and characterise pasture and browse plant species from 8+ agro-ecological zones across northern Australia to identify those species which reduce the production of methane in the rumen (low-emissions plants) and are suitable for further development. To enable efficient mapping of the existing feedbase, the project will also develop AgTech prototypes to determine how much is growing in a pasture (naturally or introduced) and measure intake by grazing cattle.

This research is supported by CRC ZNE and partners.

Cattle graze on pastures in central Queensland. Picture by North Australia Beef Research Council.

Cattle grazing in native plants in North of WA. Picture by Zoey Durmic.

Sheep accessing feed in GreenFeed unit that simultaneously measures their methane output at UWA Ridgefield Farm. Picture by Zoey Durmic

MERiL stage 2: Adapting delivery and confirming efficacy of antimethanogenic additives in grazing sheep

Project team: Dr Zoey Durmic[1] (Project leader; zoey.durmic@uwa.edu.au), Dr Stephanie Payne[1], Dr Suyog Subedi[1], Dr Joy Vadhanabhyti[1], Dr Alyce Swinbourne[2], Dr Alice Weaver[2].

Collaborating organisations: [1]UWA; [2]PIRSA-SARDI.

This project was a collaborative effort between South Australian Research and Development Institute and The University of Western Australia, with the support from federal government and the industry partners to implement practical and safe ways for producers to reduce methane emissions in Australian sheep wool and sheep meat grazing systems. This research is supported by the Department of Industry, Science and Resources (DISER), Feedworks and Australian Wool Innovation.

This project investigated a selected classes of antimethanogenic additives, in particular when implemented in common sheep grazing supplementation strategies - as feed additive or via drinking water. The study applied a systematic approach to test and validate selected antimethanogenic additives - Agolin®Ruminant (AR) and water soluble stabilized bromoform (WSSB) to be delivered to grazing sheep within Australia, either in common supplementary feeds (WA node, AR only) or in water (SA node). Methodology included *in vitro* fermentation experiments, followed by *in vivo* pen feed trial and short grazing trials. Acceptance, dose, extent and persistency of methane abatement, and other benefits when the additives are ingested by sheep were assessed.

In the WA node, the AR was first tested *in vitro* to examine forms (solid vs liquid), doses and interaction with different diet types (pellets vs loose) and common sheep feed supplements - commercial pellets, grains, or mineral loose lick. It was revealed that AR in its liquid form was the more appropriate additive form compared to the solid form, reducing methane by up to 20% when compared to control and combined with a pellet. The *in vivo* trial then aimed to confirm that AR can be successfully delivered in pellet (P-AR), or in lupins (OC-LAR), or mineral loose lick (OC-MAR) in an oaten chaff-based diet. Forty-two sheep were fed the treatments in pen feeding trial that was followed by two weeks grazing, where daily intake, productivity, methane production and effect on health were assessed. When AR was incorporated into the sheep diet, the feed was readily eaten and there were no negative effects on productivity, rumen function or adverse effects on animal health. Compared to respective controls, live weight (LG) was 15% higher in P-ARL, and concurrently, methane emission intensity was up to 19% lower in this treatment group compared to control without additive, but these effects were not significant. More prominent LW gain and methane reductions were seen with in OC-ARL-lupins and OC-ARL-lick but were subject of large variations.

In SA node, the efficacy and suitability of delivery of the two selected additives AR and WSSB via the drinking water of grazing sheep was evaluated. It was hypothesised that both AR and WSSB; (1) could be effectively delivered via an automatic water system; (2) would have no adverse effects on ewe health or productivity, and (3) have mitigation effect on methane production under grazing conditions. Both additives were successfully delivered via water, and while there were no differences in the daily water intake measured for the paddock and calculated for each ewe, the frequency of visits to the water trough was greater for AR and WSSB animals. There were no differences in LW or body condition throughout the trial; however, wool length was reduced for animals receiving AR. While the health parameters in AR ewes were not affected animals within the WSSB had greater creatine kinase levels at the end of the trial, other blood parameters were within range. Methane production (g/day) from animals within both the AR and the WSSB were reduced by 20% compared to the control ewes.

MERiL stage 3 Part 1: Confirmation of Agolin in grazing sheep

Project team: Dr Zoey Durmic[1] (Project leader; zoey.durmic@uwa.edu.au), Dr Stephanie Payne[1], Dr Suyog Subedi[1], Dr Joy Vadhanabhyti[1], Dr Alyce Swinbourne[2], Dr Alice Weaver[2], Professor Julius van Der Verf[3], Daniel Sitenei[3].

Collaborating organisations: [1]UWA; [2]PIRSA-SARDI; [3]UNE.

This project is a collaborative effort of UWA with the support from DISER and the industry partners - Australian Wool Innovation and Feedworks. It sits within the National Sheep Methane Program (NSMP) of work, that also include other partners - WA Department of Primary Industries and Regional Development, SARDI, NSW DPI and the University of New England. The NSMP is a coordinated approach to R, D&A to implement practical and safe ways for producers to reduce methane emissions in Australian sheep wool and sheep meat grazing systems.

The grazing sheep in Australia contribute to significantly to methane emissions, but the mitigation solutions that can significantly reduce their methane emissions, raise productivity, scalable and economical, easy to implement and effective in Australian grazing sheep and proven to be safe to animals, humans and the environment, are limited. Agolin® Ruminant is a commercial additive readily fed as feed additive to ruminant livestock in Australia. It is a defined blend of essential oils used in ruminant diets to increase feed intake and optimise rumen function without the use of antibiotics. In recent years, it has been shown that it can also reduce enteric methane, and it has now been certified as additive for enteric methane mitigation.

However, most of this work was carried out in Europe and under intensive systems. There is a research gap on its effect on productivity and methane mitigation in Australian grazing sheep. This project aims to study the effects of Agolin® Ruminant in Australian sheep when included as feed additive in a longer-term grazing trials. The extent and persistency of methane abatement will be examined and any other production benefits identified. A producer demonstration activity will be also included to enhance its adoption.

The main outcomes will be confirmation that Agolin® Ruminant can produce a sustained reduction in methane, concurrent with significant production benefits, while supporting animal health and wellbeing in Australian grazing sheep.

The outcomes will include supplement-methane response relationships for use in future methods by the Clean Energy Regulator, the National GHG Inventory and clear options and recommendations to producers on the use of a range of methane mitigant strategies. This will allow our extensive sheep industry sector to demonstrate a move towards carbon neutrality and will safeguard market pathways for agricultural products including wool and sheep meat, and open access for markets whereby environmentally certified product can attract premium prices.

The outcomes will also feed into NSMP and further proposals and projects. The knowledge gained through evaluating these various delivery systems will be transferable to other antimethanogenic additives in the future.

Top image: Prouductivty measurements are taken in ewes that are supplemented with Agolin® Ruminant while grazing at UWA Ridgefield Farm. Picture by Dr Zoey Durmic.

Bottom image: Dr Suyog Subedi delivering feed additive to grazing sheep at UWA Farm Ridgefield.

MERiL stage 3 Part 2

Project team: Dr Zoey Durmic[1] (Project leader; zoey.durmic@uwa.edu.au), Dr Stephanie Payne[1], Dr Suyog Subedi[1], Dr Joy Vadhanabhyti[1], Dr Alyce Swinbourne[2], Dr Alice Weaver[2], Professor Julius van Der Verf[3], Daniel Sitenei[3], Dr Augusto Imaz[4].

Collaborating organisations: [1]UWA; [2]PIRSA-SARDI; [3]UNE; DPI NSW[4].


Research partners from AWI, PIRSA, UWA, NSW DPIRD and UNE met at the PIRSA Turretfield Research Centre in 2024 for planning meeting. Picture by Dr Zoey Durmic.

The MERiL3-2 grant provides a further $3 million from the Australian Government for National Sheep Methane Program (NSMP) partners and aims to investigate the efficacy and delivery of sheep combined antimethanogenic feed additives to improve methane abatement, as well as sheep productivity. This research at UWA is supported by the DISER, Feedworks, Australian Wool Innovation and Proagni.

Sheep accessing GF in MERiL3-1.


The project builds on previous work from collaborating organisations in the NSMP looking at efficacy and delivery of various sheep feed additives. This project will validate combinations of existing additives that are deemed to be cost effective and close to market-ready, and that are likely to have improved effects on methane abatement as well as productivity. Furthermore, we will be investigating practical aspects of delivering antimethanogenic feed additive to grazing sheep in different production systems and environments across Australia. At the end of the project, we will be able to provide validated mitigation and productivity claims of sheep feed additives and how to deliver those to grazing sheep.


Sheep accessing lickfeeder in Meril3-2.


Sheep near lickfeeder in MERiL3-1.

Development of a standardised training tool for the assessment of sperm morphology

Project team: Katherine R Seymour[2] (Project leader; katherine.seymour@sydney.edu.au), Dr Kelsey Pool[1], Professor Simon de Graaf[2], Dr Jessica Rickard[2], Dr Taylor Pini[3].

Collaborating organisations: [1]UWA; [2]The University of Sydney; [3]The University of Queensland.

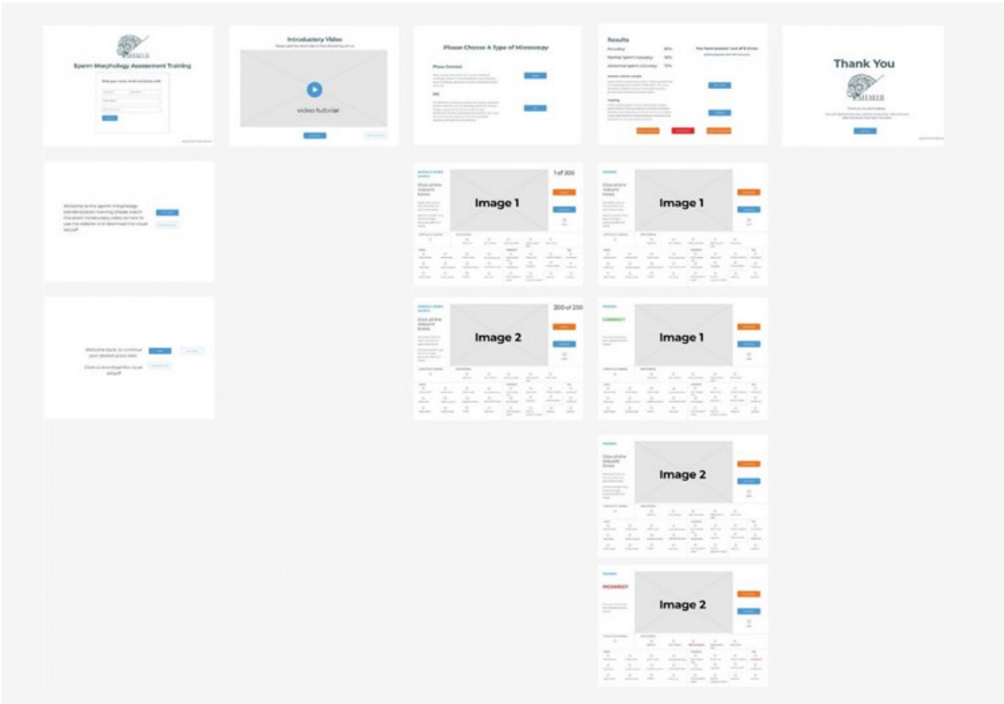
The assessment of sperm morphology is a widely used, yet inherently subjective, method to evaluate male fertility in livestock. These assessments play a critical role in determining breeding soundness, the suitability of animals for artificial insemination programs, and even sale value at stud auctions. However, despite its significance, there is currently no standardised training tool to ensure consistent and accurate assessments across practitioners, laboratories, or species.

Traditional training methods such as lecture-based learning or direct side-by-side mentoring, are labour-intensive, lack scalability, and do not effectively address the high inter- and intra-observer variability associated with the evaluation of sperm morphology.

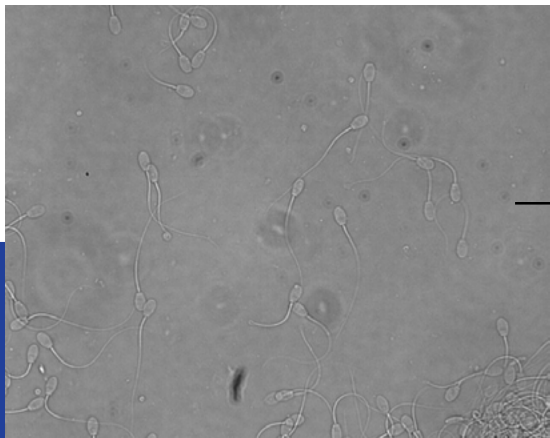
This proof-of-concept study aimed to fill this gap by developing the first interactive, standardised training tool for the assessment of sperm morphology that integrates principles of machine learning and ground-truth data to train users on a sperm-by-sperm basis.

The project involved the capture of 3,600 field-of-view (FOV) images at 40× magnification using DIC (differential interference contrast) microscopy on the sperm from 72 rams. A novel machine learning algorithm was used to isolate 9,365 individual sperm cells from these images. Of these, 4,821 sperm images were classified by three expert morphologists with 100% consensus, ensuring the highest standard of accuracy for training purposes.

These images were then incorporated into a custom-built web interface that allows users to receive immediate feedback, test their accuracy, and train independently at their own pace. The tool program can be adjusted to be specific to other species, microscope types, and classification systems, offering broad applicability.



User interface for the 'sperm morphology assessment standardization training tool' generated using Figma.



An image of ram spermatozoa, highlighting the difficulty and subjectivity of making an assessment of morphology using standard methodology.

Future research will evaluate the tool's effectiveness in improving accuracy and reducing observer variability. If successful, it could revolutionise training in reproductive biology across veterinary, agricultural, and medical fields in Australia and globally.

No external funding was received for this study.

Ancestral lineages of dietary exposure to an endocrine disrupting chemical drive distinct forms of transgenerational subfertility in an insect model

Project team: Dr Kelsey Pool[1] (Project leader; kelsey.pool@uwa.edu.au), Associate Professor Dominique Blache[1], Callum Connolly[1], Raveena Hewa Gajanayakage[1].

Collaborating organisations: [1]UWA.

Insects around the world are experiencing alarming population declines, with reduced fertility being a key driver linked to human-induced environmental changes. This study investigated how a common dietary endocrine disrupting chemical (EDC), equol, affects the reproductive capacity of *Drosophila melanogaster* across three generations. Equol is a phytoestrogen that is found in many agricultural plants that are consumed by insects. Using a novel flow cytometry method to assess live sperm function, the research showed that reproductive impairments persist even when non-exposed individuals are introduced into the breeding population.

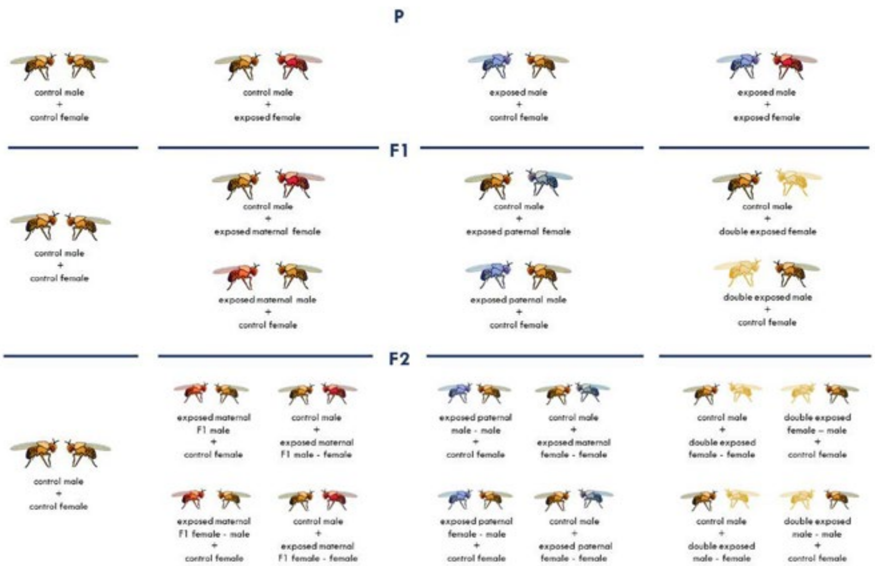
The study found that ancestral exposure to equol caused long-term subfertility in both male and female offspring, with male fertility most severely affected. Sperm from equol-exposed lineages displayed DNA damage, metabolic stress, and reduced viability. These effects varied depending on whether the maternal, paternal, or both lineages had been exposed. Across generations, male offspring consistently exhibited compromised sperm function and smaller seminal vesicles, a trait associated with reduced fertility.

Interestingly, equol exposure also skewed offspring sex ratios in favour of females. This may be due to hormonal interference with sex differentiation or female-driven sex allocation in response to low-quality male partners. While equol altered the expression of key reproductive genes in the directly exposed generation, these genetic changes were not maintained in subsequent generations, suggesting epigenetic rather than genetic inheritance.

The findings provide new evidence that dietary EDCs, such as those found in crops, can induce transgenerational reproductive dysfunction in insects. The outcomes highlights the potential role of phytoestrogens as a contributor to declines in insect populations, not only through direct toxicity but through subtle, long-term impacts on fertility. Given the prevalence of these compounds in agricultural landscapes, the study suggests that the homogenisation of insect diets could have serious ecological consequences. Further research is needed to determine whether fertility can recover over subsequent generations.

This study was supported by the Lefroy Bequest.

Oestrogenic clover, commonly found in WA sheep and cattle pastures, also produces oestrogenic metabolic equol in livestock when grazed.



The study design used to trace the impacts of oestrogenic metabolite equol on fertility through multiple generations.

Finding biomarkers of experience in animals

Project team: Associate Professor Dominique Blache[1] (Project leader; dominique.blache@uwa.edu.au), Sarah Babington[1], Alan J. Tilbrook[2], Shane K. Maloney[1], Jill N. Fernandes[2], Professor Tamsyn M. Crowley[3,4], Luoyang Ding[1,5], Archa H. Fox[1], Song Zhang[1], Elise A. Kho[2], Daniel Cozzolino[2], Timothy J. Mahony[2].

Collaborating organisations: [1]UWA; [2]The University of Queensland; [3]University of New England; [4]Deakin University; [5]Yangzhou University, China.

Public concern for animal welfare is on the rise, highlighting the need for objective methods that assess how animals experience various situations. While current behavioural, physiological, and neurobiological indicators can confirm the absence of severe negative states, they fall short of capturing the full spectrum of an animal's experience, including positive states.

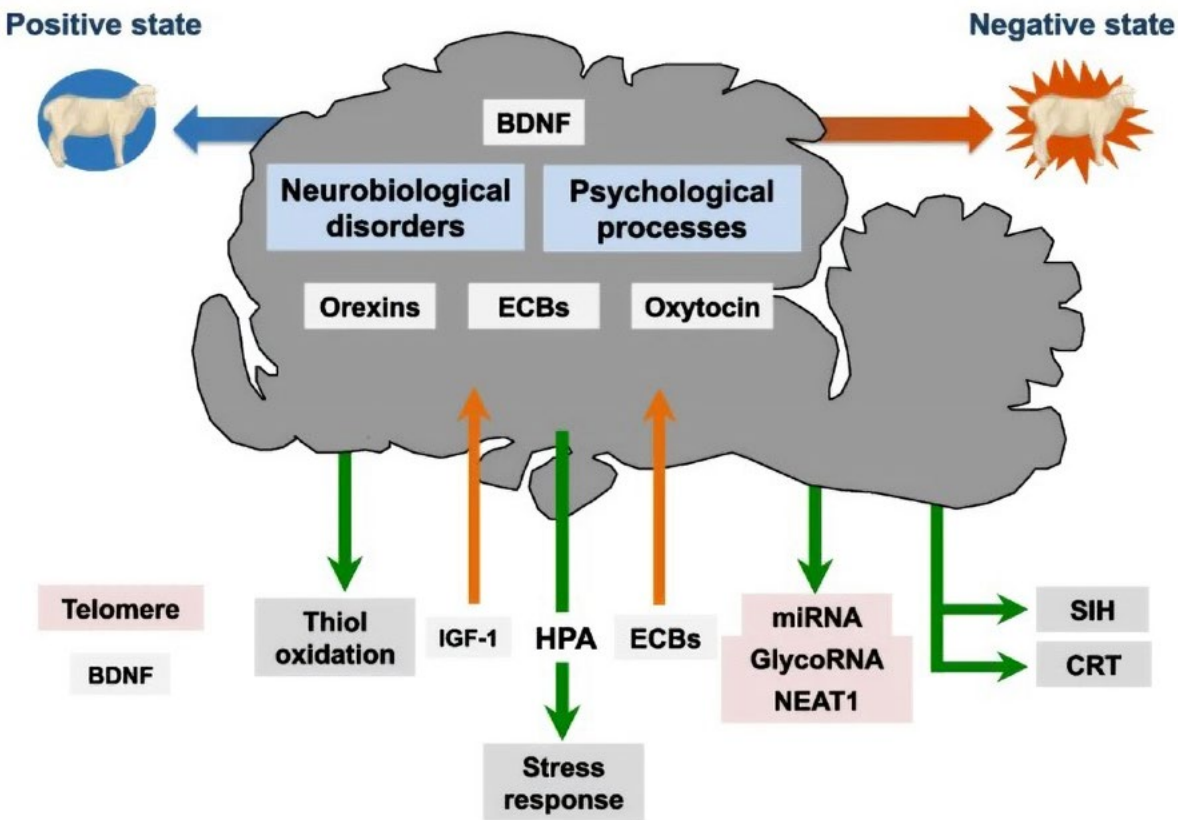
This review draws upon knowledge from human biomedical science to propose a list of candidate biological markers, or biomarkers, that could more accurately reflect the experiential state of non-human animals.

Historically, Western societies have increasingly recognised the sentience of animals, prompting calls for improved welfare standards. This societal shift has driven scientific efforts to better understand and assess animal welfare using evidence-based approaches. Although existing indicators such as cortisol levels, heart rate, and body posture offer insight into stress responses, they do not directly measure the animal's subjective experience. Recognising this gap, the authors propose potential biomarkers grouped by their main function: endocrine, oxidative stress, non-coding molecular, and thermobiological.

These biomarkers have been shown to have an association with psychological or neurological states in humans or animal models, suggesting their relevance in welfare science. However, challenges remain, particularly in validating these biomarkers and ensuring they can be applied in real-world, on-site conditions. Technological advancements will be essential to make these tools accessible and practical for those caring for animals.

In conclusion, no single biomarker is likely to reflect the full range of animal experience. A combined or systemic approach, supported by further research and innovation, is needed to enhance how we assess the welfare of animals. By focusing on indicators that capture not just the absence of suffering but also the presence of positive experience, this review supports a more holistic understanding of animal welfare.

This research was supported by MLA grant P.PSH.1232, the APRI Ltd grant 5A-113, The University of Queensland and UWA.



Schematic summary of potential biomarkers of the experiential state of an animal. These biomarkers are potentially involved in the shift to a more positive experiential state.

Novel pathways linked to the expression of temperament in Merino sheep: a genome-wide association study

Project team: Professor Mengzhi Wang[2] (Project leader; mengzhiwangyz@yzu.edu.au), L. Ding[1,2,4], E.R. Colman[3], Y. Wang[2,4], M. Ramachandran[1], Professor Shane K. Maloney[1], N. Chen[4], J. Yin[4], L. Chen[5], E.V. Lier[3], Associate Professor Dominique Blache[1].

Collaborating organisations: [1]UWA; [2]Yangzhou University, China; [3]Universidad de la República, Uruguay; [4]Xinjiang Academy of Agricultural Reclamation Sciences, China; [5]Nanjing Medical University, China.

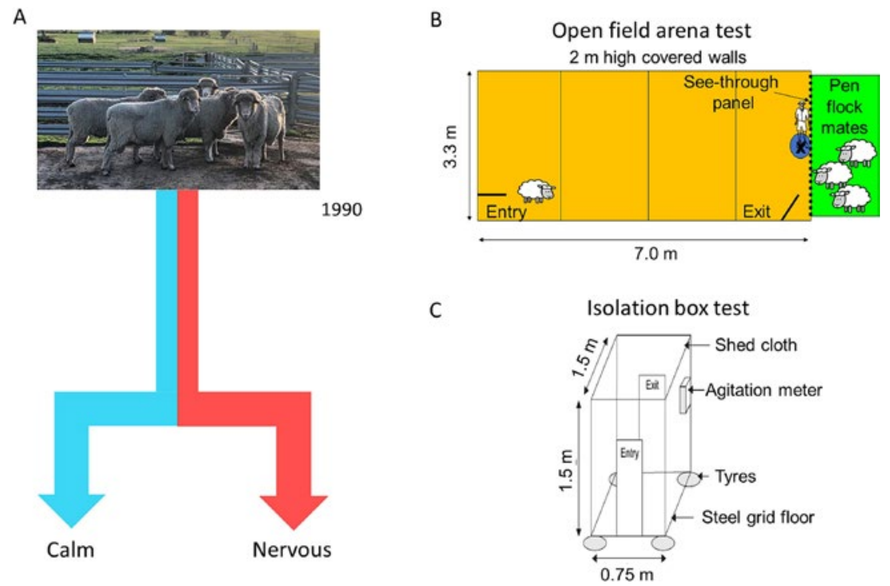
Animal temperament is a complex trait that reflects the behavioural and emotional responses of an animal to environmental stimuli, influenced by brain circuits that are not yet fully understood in non-human animals or humans. Temperament affects many biological processes, including reproduction and activation of the stress axis. It is relatively stable and heritable, with estimates around 0.4 in Merino sheep, indicating a strong genetic basis. Previous studies have identified candidate genes that are associated with temperament in various species using candidate gene association and genome-wide association studies (GWAS). However, because temperament involves complex neural circuits and multiple biological pathways, GWAS are better suited to uncover the many genes with small effects that are spread throughout the genome.

Domesticated animals generally show less variation in temperament than wild or experimentally selected species, such as the famously tame and aggressive fox lines that have been bred over 50 generations. This study leverages two lines of Merino sheep that have been selectively bred for calm or nervous temperament for more than 20 generations, aiming to better understand the genetic basis of temperament in farm animals.

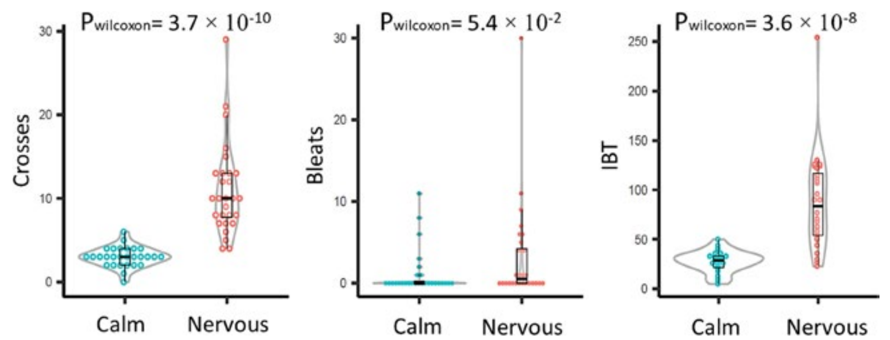
Using GWAS on these lines and a commercial sheep population, the research identified 2,729 single nucleotide polymorphisms (SNPs) that differed significantly between the calm and nervous sheep. Of those, 2,084 SNPs were validated as associated with temperament traits in the commercial flock. Genomic analysis highlighted 81 candidate genes that were linked to temperament, with nearly half also associated with disorders of social behaviour in humans. Several genes overlapped with those linked to aggression and tameness in red foxes, indicating shared genetic pathways across species. Five candidate genes were additionally connected to production traits in livestock.

These findings suggest that temperament is influenced by a complex network of genes that affects nervous system functions and behaviour. The results provide a foundation to incorporate temperament traits into genetic selection in sheep, with potential benefits for both animal welfare and production outcomes. This research advances understanding of the genetics of temperament in domestic animals and its similarities to the genetics of social behaviour in other species.

This research was supported by the key program of State Key Laboratory of Sheep Genetic Improvement and Healthy Production, the National 14th Five-Year Plan Key Research and Development Program, the Comisión Sectorial de Investigación Científica (CSIC Udelar, Proyecto I+D, 2018, number 287), and the Priority Academic Program Development of Jiangsu Higher Education Institutions.



The breeding on temperament in Merino sheep at the UWA Farm Ridgefield. The temperament selection process began in 1990 (A) and was used to generate the present populations of calm and nervous sheep in the UWA temperament flock using an open-field arena test (B) and an isolation box test (C) for more than 20 generations to select on temperament traits. Sheep from the extremes of scores on the two behavioural tests were used to breed calm and nervous populations every year.



Behavioural traits in sheep classified as "calm" and "nervous" from the UWA commercial flock.

Assessment of loliolide extracted from *Biserula pelecinus,* present during in vitro oocyte maturation, on fertilisation and embryo development in sheep

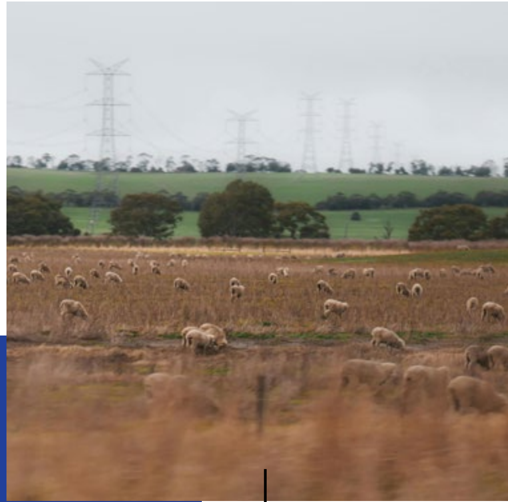
Project team: Emeritus Professor Graeme Martin (Project leader; graeme.martin@uwa.edu.au), Anna Amir[1], Azizah Algreiby[2], J.M. Kelly[3], David Kleemann[3], Zoey Durmic[1], Associate Professor Gavin Flematti[1], Associate Professor Dominique Blache[1].

Collaborating organisations:
[1]UWA; [2]Qassim University, Saudi Arabia; [3]Turretfield Research Centre, South Australia.

The introduction of new forage species for grazing livestock demands thorough evaluation, particularly for plant secondary compounds (PSCs) that may impact reproduction. *Biserrula pelecinus,* a promising legume that is adapted to Australian conditions, has attracted attention due to previous findings that suggest its extracts could enhance fertilisation and embryo development in sheep. This study aimed to validate those findings using in vitro embryo production (IVEP) and to identify any bioactive compounds that are responsible for that effect.

Methanol–chloroform extracts of *B. pelecinus* were fractionated and tested during the in vitro maturation (IVM) of sheep cumulus–oocyte complexes (COCs). Parameters of embryo development such as cleavage, blastocyst formation, and total cell number, were assessed. One fraction (BP-6) reduced blastocyst rates at 100 µg/mL, but this effect was not observed at a higher dose. Further analysis identified loliolide as the most abundant compound in BP-6. However, supplementation with purified loliolide at various concentrations had no significant impact on any reproductive outcome.

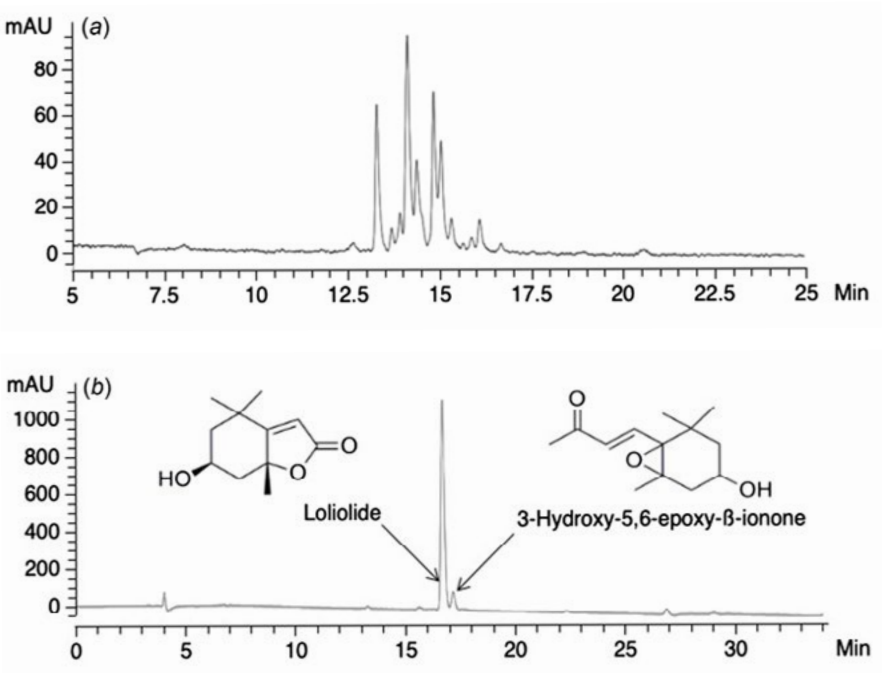
While all COCs reached the blastocyst hatching stage regardless of treatment, the results indicate that *B. pelecinus* contains PSCs that are capable of subtly affecting early embryo development. Importantly, loliolide was not responsible for the previously observed positive effects, suggesting those earlier findings may have been incidental.



Herd of Sheep

In conclusion, although *B. pelecinus* does not appear to pose a major threat to reproductive performance in sheep, caution is still warranted when animals graze heavily on this legume. The study reinforces the value of IVEP as a sensitive, cost-effective tool for screening forage species for reproductive toxicity and to identify the mechanisms of action of plant-derived compounds.

This research was supported by UWA, University Putra Malaysia, Mike Carroll Travelling Fellowship and Qassim University, Saudi Arabia.



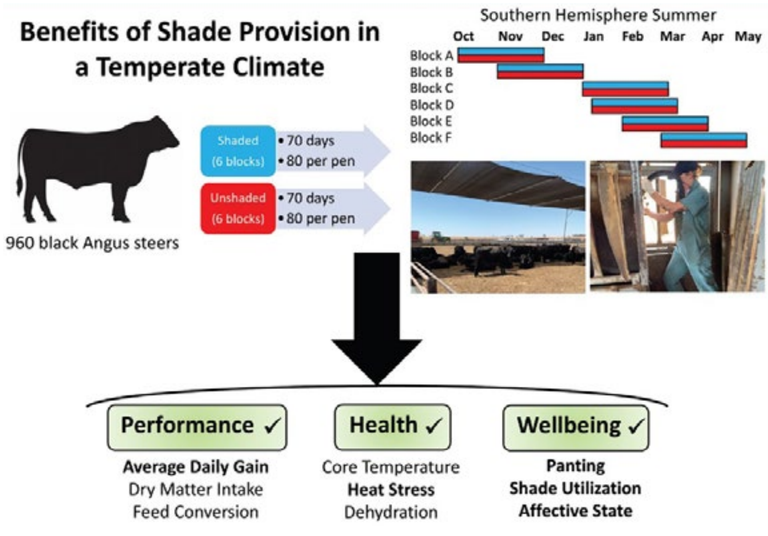
(a) HPLC chromatogram of a crude methanolic extract of B. pelecinus and (b) a fraction of BP-6, showing the presence of only two major compounds. Loliolide accounted for more than 80% of the sample.

Welfare and performance benefits of shade provision during summer for feedlot cattle in a temperate climatic zone

Project team: Associate Professor David W. Miller[2] (Project leader; d.miller@murdoch.edu.au), Anne L. Barnes[2], Teresa Collins[2], Liselotte Pannier[2], Joshua Aleri[2], Professor Shane K. Maloney[1], Fiona Anderson[2].

Collaborating organisations: [1]UWA; [2]Murdoch University.

With rising global temperatures and increasing concern for animal welfare, the use of shade in cattle feedlots is gaining interest, even in regions that are considered at low risk for heat stress. This study examined whether shade provision provided benefits to lot-fed Black Angus cattle in a temperate climate zone of Western Australia, where the risk of heat stress is classified as mild. Over a southern hemisphere summer, six groups of 160 steers (80 shaded, 80 unshaded) were observed for 70 days to assess performance, health, and welfare outcomes.



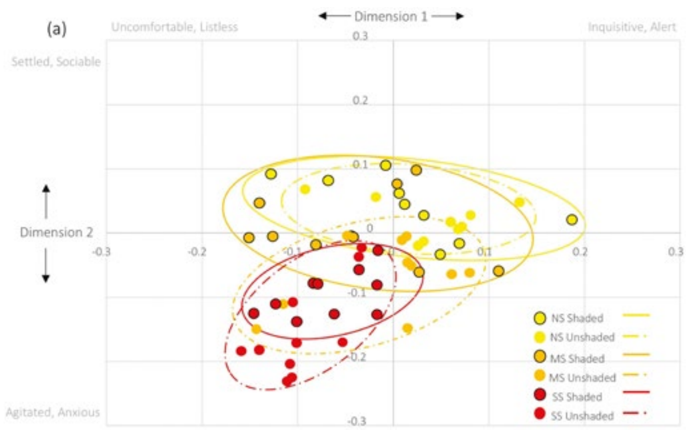
Graphical Abstract.

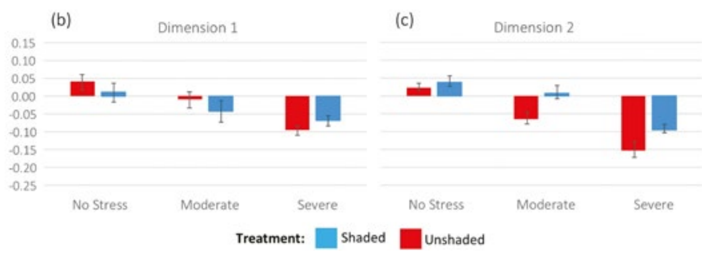
Cattle provided with shade had a modest increase of 0.13 kg in average daily gain, though this was not statistically significant. Dry matter intake was similar across shaded and unshaded groups. Physiological indicators, including panting and rumen temperature, revealed that cattle were generally able to thermoregulate effectively, even during the hottest periods. However, behavioural observations and qualitative behavioural assessment (QBA) revealed notable welfare benefits from shade. Shaded cattle, particularly those in moderate heat stress conditions, appeared more settled and sociable, while unshaded cattle were more agitated and anxious.

These findings suggest that shade improves the affective state of cattle, an important but often overlooked dimension of animal welfare. Despite industry hesitation due to the perceived low economic return in cooler regions, this study provides evidence that shade structures offer tangible welfare gains and probably some performance improvement. The study also underscores that animal responses to thermal stress are complex, influenced not only by temperature but also by humidity, solar radiation, and wind, making indices like the Temperature Humidity Index (THI) a useful tool for decision-making.

Importantly, this is the first known study to report on the impact of shade on the affective state of feedlot cattle. The findings offer valuable insights for Australian lot feeders, particularly in temperate zones, and reinforces the need for multidimensional approaches to livestock welfare that go beyond productivity. The research sets a benchmark for future studies and may encourage broader adoption of shade in commercial feedlot systems.

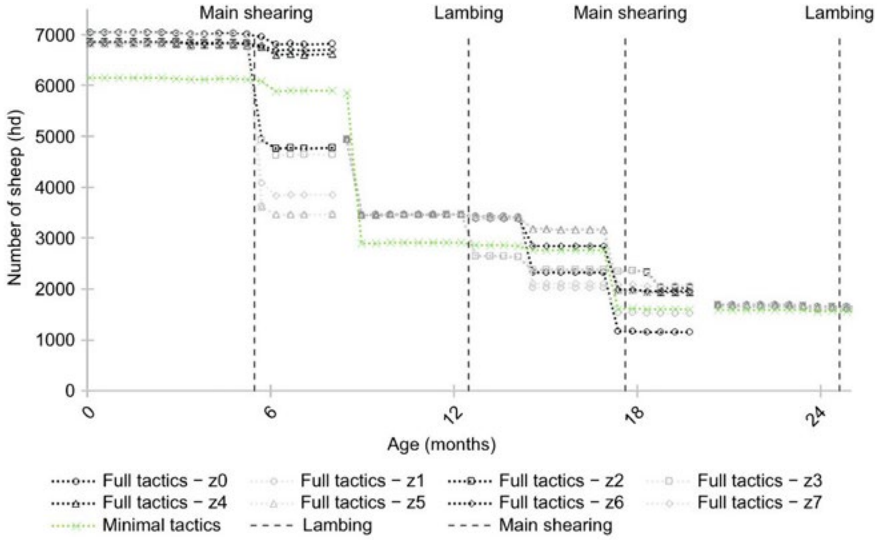
This research was supported by UWA and Murdoch University MLA with matching funds provided by the Australian Government.





Position of (a) individual cattle from the shaded (black bordered circles) and unshaded (non-bordered circles) treatments on the 2 main PCA dimensions characterized their THI category as no stress, moderate stress, and severe stress. The corresponding colored elipses visually highlight the clustering of the cattle on the dimensions and the effect of THI level and shade provision. Graphical summary of treatment × THI effects for (b) PCA dimension 1 and (c) PCA dimension 2 scores for the shaded and unshaded treatments. Values are means ± SE.

Identifying high-value tactical livestock decisions on a mixed enterprise farm in a variable environment



Sheep numbers by age group in each weather-year. Note: There is a gap in the graph at 8 months and 20 months, which is the beginning of the next year, at which point all weather years have the same opening numbers, and they can then diverge again.

Project team: Michael Young[1] (Project leader; youngmr44@gmail.com), John Young[2]; Emeritus Professor Ross S. Kingwell[1,3,4], Professor Philip E. Vercoe[1].

Collaborating organisations: [1]UWA; [2]Farming Systems Analysis Service, Kentdale, WA; [3]DPIRD; [4]Australian Export Grains Innovation Centre.

Australia's highly variable climate, characterised by alternating periods of drought and flooding, poses significant challenges for dryland farming systems, especially those involving livestock. In such mixed-enterprise systems, profitability can fluctuate dramatically, creating a demand for responsive management strategies. This study explored how tactical livestock decisions, those made in response to unfolding seasonal conditions, can optimise farm profitability in the Great Southern region of Western Australia.

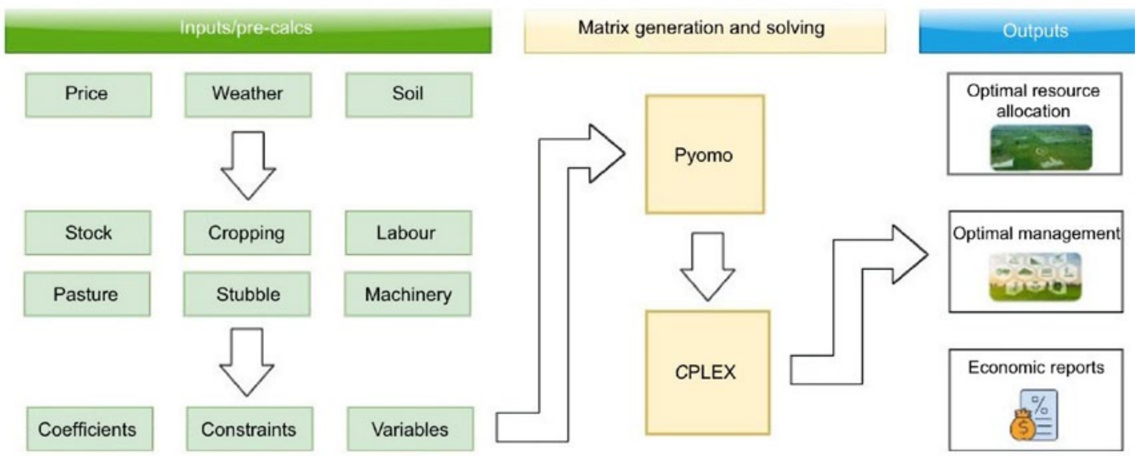
Using a whole-farm optimisation model, the researchers assessed the economic value of five key livestock management tactics: the timing of sheep sales, adjustments to pasture area, rotational grazing, crop grazing, and changes to sheep nutrition. The incorporation of these tactics into annual planning can increase expected farm profit by around 16%, with individual tactics contributing between A$7,704 and A$53,171. Importantly, these tactics enable farmers to adapt their management to seasonal realities, rather than relying solely on long-term strategic planning or diversification.

The study fills a critical research gap by focusing on livestock within mixed-farming systems, an area historically overlooked in favour of crop-based tactical research. Livestock contribute not only financially—comprising roughly 21% of total farm income in Western Australia—but also play an integral role in sustainable farming practices by utilising crop residues, improving soil health, and providing year-round employment in rural areas.

The findings highlight that short-term tactical management is not only viable but essential in variable climates. Such management enables farmers to navigate risks and make informed, timely, decisions that directly affect their bottom line. Importantly, the model developed in this study accounts for year-to-year climate variability and allows for nuanced adjustments to farm strategy, unlike traditional models which often oversimplify these dynamics.

Overall, the research underscores the financial and strategic importance of building tactical decision-making capacity in mixed-enterprise farming. It provides a strong case for supporting farmers to develop adaptive skills that enhance profitability and resilience in the face of climate uncertainty.

This research was supported by DPIRD.



Visual representation of AFO.

Lake Kununurra, Western Australia.

3

Water for Food Production

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 20 per cent of which is irrigated. Irrigated agriculture provides forty per cent of the world's food and can increase crop yield by two to four times when compared to 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 though 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.

Theme Leaders

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A multi-sensor drought index for improved agricultural drought monitoring and risk assessment in the heterogeneous landscapes of the China–Pakistan Economic Corridor (CPEC)

Project team: Associate Professor Yi Li [2,3] (Project leader; liyi@nwafu.edu.cn), Dr Muhammad Ismail[2,3], Professor Ben Niu[2,3], Dr Mubashir Ali Ghaffar[2,3], Dr Muhammad Amjad Saleem[2,3], Hackett Professor Kadambot H.M. Siddique[1].

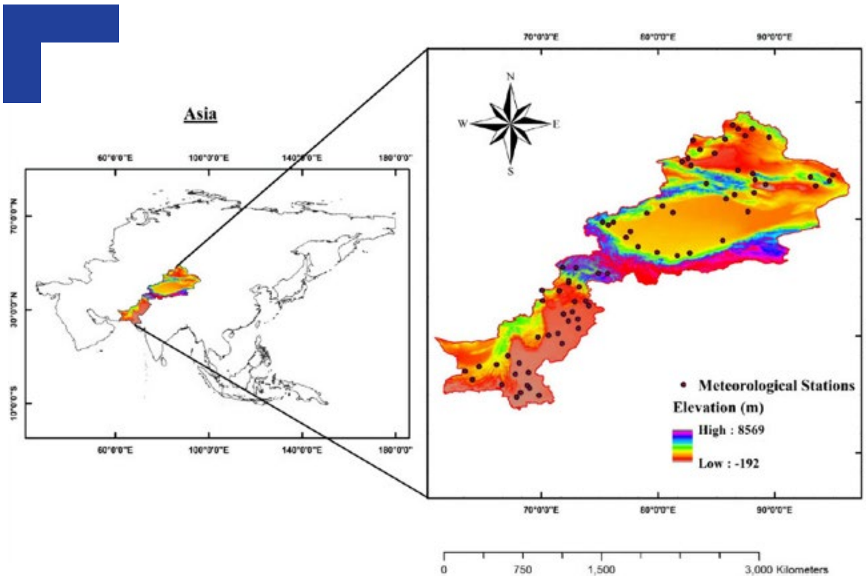
Collaborating organisations: [1]UWA; [2]College of Water Resources and Architectural Engineering, China; [3]Northwest A&F University, China.

Drought is a significant global concern, causing economic damage and posing risks to agriculture, particularly in regions where water resources are limited. Traditional methods of drought monitoring, which rely on individual variables like precipitation, temperature, or soil moisture, often fall short in addressing the complexities of drought conditions.

This study seeks to improve drought monitoring and risk assessment in the China-Pakistan Economic Corridor (CPEC) by developing a multi-sensor drought index that combines station-based and remote sensing data.

Researchers introduced two composite drought indices (CDIs): the Principal Component Analysis Drought Index (PSDI) and the Gradient Boosting Method Drought Index (GBMDI). These indices combine in-situ data—such as the Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration Index (SPEI), and the Self-Calibrated Palmer Drought Severity Index (SC-PDSI)—with remote sensing indicators, including the Vegetation Condition Index (VCI), Soil Moisture Condition Index (SMCI), Temperature Condition Index (TCI), and Precipitation Condition Index (PCI).

By integrating multiple datasets, this approach provides a more comprehensive assessment of drought severity across CPEC's diverse landscapes. The indices were validated using historical drought events and winter wheat yield data from 2003 to 2022. Results showed extreme droughts were more frequent in the 1990s and 2010s, with winter droughts proving more severe than summer droughts.



Location of the study area with elevations and spatial distribution of meteorological stations.

Arial photo taken on Aug. 5, 2019 shows the view of Sukkur-Multan Motorway in central Pakistan's Multan. The construction of the 392-km Sukkur-Multan Motorway under the China-Pakistan Economic Corridor (CPEC) has been completed.(Photo: Xinhua).

Shorter monitoring intervals (1–3 months) captured more fluctuations, while longer periods (6–12 months) indicated prolonged droughts.

GBMDI demonstrated the strongest correlation with observed drought events and station-based indices, proving to be a more accurate tool for monitoring drought conditions. It also effectively predicted the impact of drought on winter wheat yields, highlighting its value for agricultural risk management.

The integration of remote sensing data in GBMDI makes it particularly useful in areas with limited ground-based observations, offering a more adaptable and reliable approach to drought assessment. By improving accuracy in drought detection, this research supports sustainable agricultural practices and enhances resilience to climate variability in drought-prone regions like CPEC.

This research is supported by NNSFC.

Diversified crop rotations improve crop water use and subsequent cereal crop yield through soil moisture compensation

Project team: Adjunct Professor Xiaolin Yang[3] (Project leader; yangxiaolin429@cau.edu.cn), Bo Wang[2,3], Guiyan Wang[4,5], Jos van Dam[6], Coen Ritsem[6], Hackett Professor Kadambot H.M. Siddique[1], Taisheng Du[2,3], Shaozhong Kang [2,3].

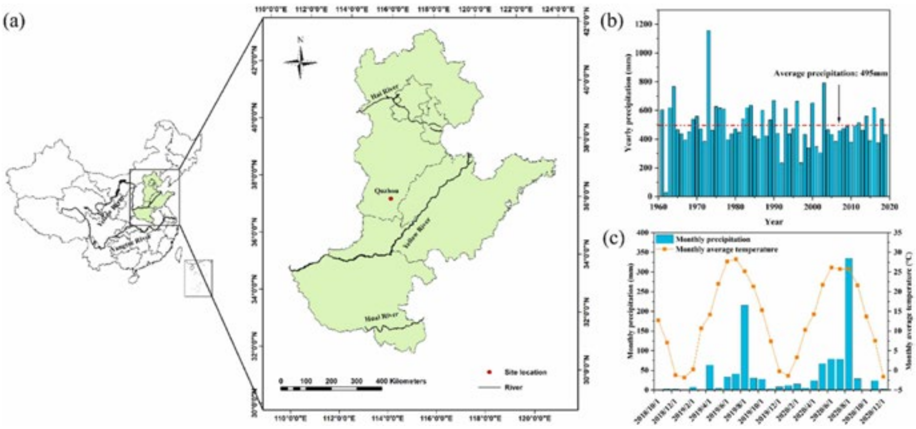
Collaborating organisations: [1]UWA; [2]State Key Laboratory of Efficient Utilization of Agricultural Water Resources, China; [3]China Agricultural University, China; [4]State Key Laboratory of North China Crop Improvement and Regulation, China; [5]Hebei Agricultural University, China; [6]Wageningen University and Research, the Netherlands.

The North China Plain (NCP) has faced significant challenges from over-reliance on conventional winter wheat–summer maize double cropping, which has contributed to declining groundwater tables and environmental stresses. This two-year study explored the potential benefits of introducing five diversified crop rotations involving spring crops (sweet potato, soybean, peanut, spring maize, and millet) into the NCP's cereal cropping system, aiming to improve water efficiency and crop yield.

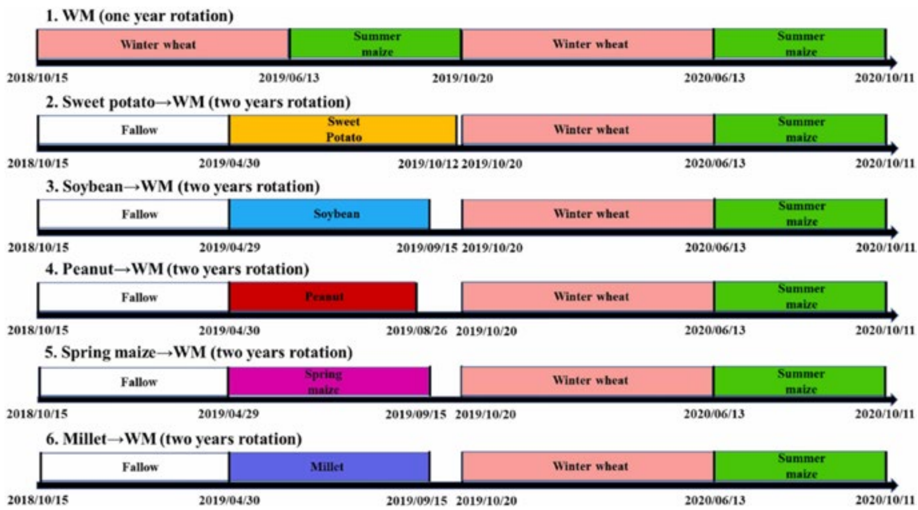
The research found that these diversified rotations reduced actual crop evapotranspiration by 7–12% and net groundwater use by 21–31% compared to the conventional WM system. Notably, rotations incorporating sweet potato and peanut produced higher yields, with an increase in economic benefits of 50% and 7%, respectively, and water productivity improvements ranging from 24% to 68%. The shallow-rooted crops in these rotations improved soil water storage in the 0–180 cm soil layer by 3–9% before the wheat planting season, ensuring better soil moisture availability for subsequent crops. This water use efficiency was due to the shallow-rooted crops absorbing moisture primarily from the upper 80 cm of the soil, allowing deeper-rooted wheat to access water from the lower layers.

The benefits of these diversified rotations extended beyond water conservation. Total grain yields of wheat and maize increased by 4–11% compared to conventional WM, demonstrating the positive impact on crop productivity. These findings suggest that introducing shallow-rooted crops into the crop rotation system can mitigate groundwater depletion while increasing overall agricultural output.

The study concludes that such diversified crop rotations are a promising solution for balancing food production and sustainable water use in the NCP and similar water-scarce regions.



Location of Quzhou experiment station in North China Plain.



Crop rotation design and crop sequences with sowing and harvest time.

This research is supported by NNSFC, State Key Laboratory of North China Crop Improvement and Regulation, and CSC.

Optimizing biochar application rates for improved soil chemical environments in cotton and sugarbeet fields under trickle irrigation with plastic mulch

Project team: Associate Professor Yi Li [2,4] (Project leader; liyi@nwafu.edu.cn), Xingyun Qia [2,4], Guang Yang[3], Zhenan Hou[4], Penghui Shi [2,4], Shibin Wang [2,4], Xiaofang Wang [2,4], Jiaping Liang [2,4], Benhua Sun[4], Shufang Wu[2,4], Hao Feng[4], Xiaohong Tian[4], Qiang Yu[4], Xiangwen Xie[5], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]Key Lab of Agricultural Soil and Water Engineering in Arid and Semiarid Areas, China; [3]College of Water Conservancy & Architectural Engineering, China; [4]Northwest A&F University, China; [5]Xinjiang Academy of Agricultural Sciences, China.

Biochar can potentially change the soil physico-chemical environment significantly, but its impact on the soil chemical environment is poorly understood.

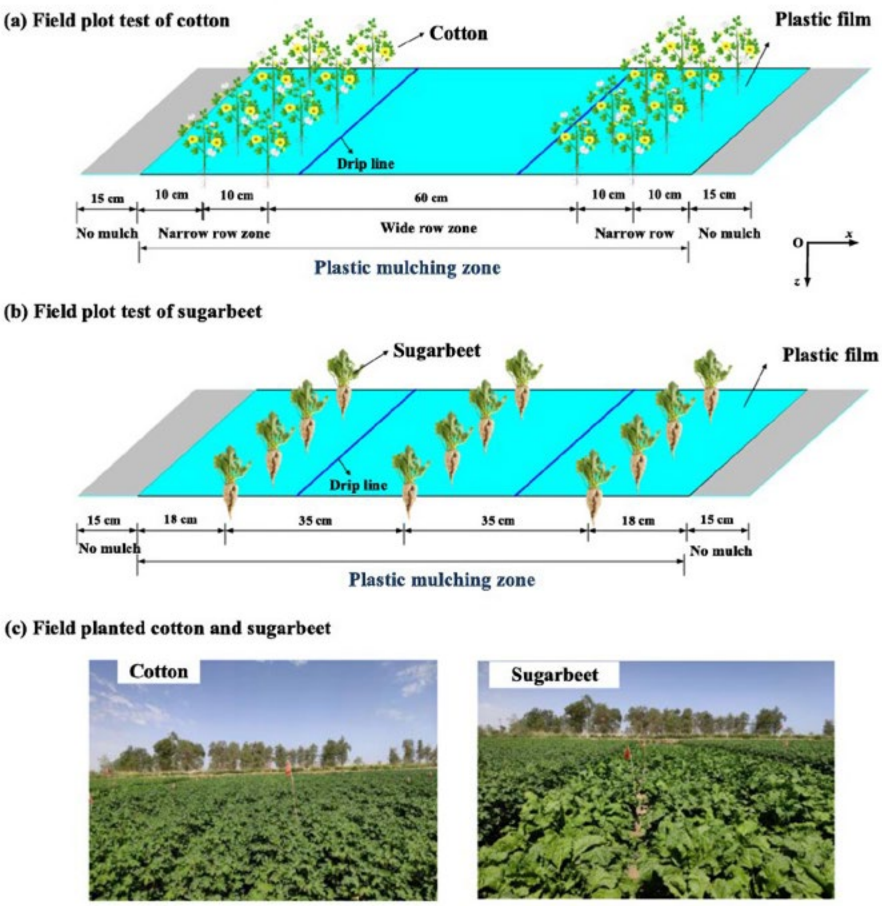
This study investigates the impact of biochar application on the soil chemical environment in saline-alkali fields growing cotton and sugarbeet in Xinjiang, China. A three-year field experiment, conducted from 2018 to 2020, explored the effects of different biochar application rates (BARs) on soil Na+, K+, nutrient contents (NO3−-N, NH4+-N, soil organic carbon, available phosphorus, and available potassium), and soil salinity.

The experiment included BAR treatments of 0, 10, 50, and 100 t ha−1 in 2018, adjusted to 0, 10, 25, 50, and 100 t ha−1 in 2019, and 0, 10, 25, and 30 t ha−1 in 2020. The results showed that increasing BAR positively influenced the soil Na+, K+, and nutrient contents. In the horizontal direction, plastic mulched zones had lower Na+ and K+ contents than bare soil, while higher values were observed in the 0–40 cm soil layer. Sugarbeet showed a greater reduction in soil ion contents compared to cotton. Biochar application significantly increased the soil nutrient contents, with the sugarbeet fields showing the highest increase, particularly for NO3−-N.

Soil salinity was highest in the first year but decreased in subsequent years due to irrigation measures, particularly in the crop cultivation layer (0–60 cm). The optimal BAR for improving the chemical environment was found to be 10 t ha−1, significantly enhancing soil nutrient accumulation and reducing soil salinity.

These findings suggest that biochar application can improve soil quality in saline-alkali fields, particularly for crops like sugarbeet. Further research is necessary to evaluate the long-term impacts of biochar on soil chemical properties and crop productivity in these regions.

This research was jointly supported by NNSFC, the Key Research and Development Program of Xinjiang, and the High-end Foreign Experts Introduction Project.



Test site arrangement diagram of cotton and sugarbeet. Fig. 1c shows cotton at the squaring stage and sugarbeet at the sugar accumulation stage.

Ephemeral gully development in the hilly and gully region of China's loess plateau

Project team: Professor Shufang Wu[2] (Project leader; wsfjs@163.com), Boyang Liu[2], Biao Zhang[2], Ziming Yin[2], Bai Hao[3], Hao Feng[2], Hackett Professor Kadambot H.M. Siddique[1].

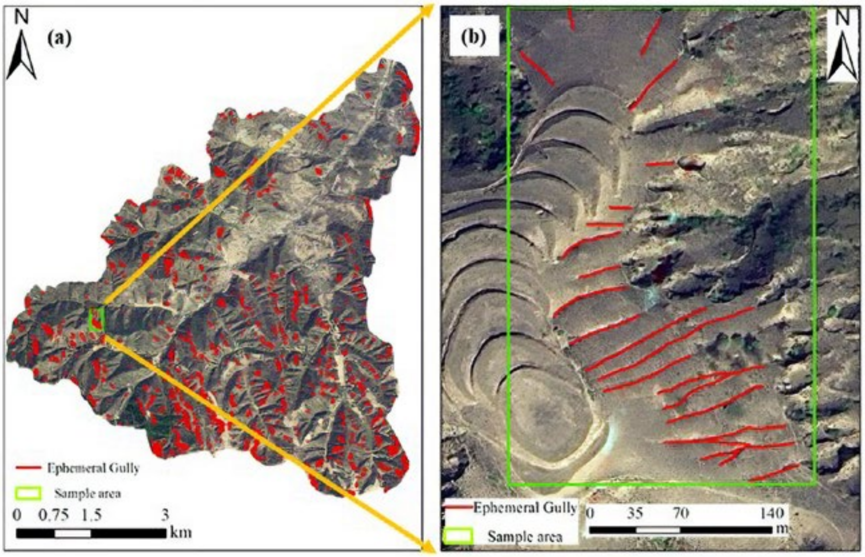
Collaborating organisations:
[1]UWA; [2]Northwest A&F University, China; [3]Sichuan Expressway Construction & Development Group Co., Ltd, China.

Ephemeral gully erosion is a major contributor to soil degradation, reducing land productivity and limiting sustainable land use on the Loess Plateau, China.

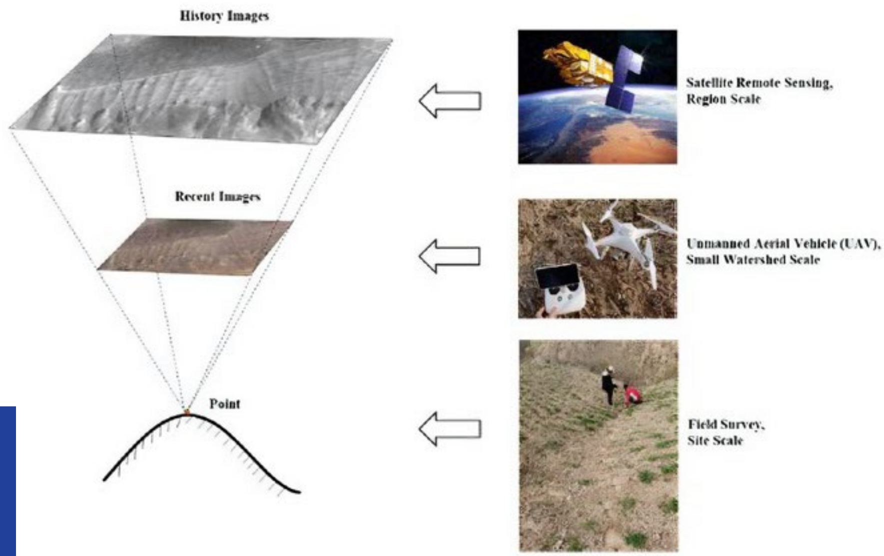
While previous studies have focused on individual gullies or specific slope types, there has been limited research on the spatial and temporal changes in ephemeral gully erosion at the watershed scale. This study used high-resolution remote sensing imagery, unmanned aerial vehicles (UAVs), and field investigations to analyse the development and evolution of ephemeral gullies in the Zhoutungou watershed over a 12-year period (2009–2021).

The results show a significant decrease in the number of ephemeral gullies, from 4495 in 1999 to 2312 in 2021, largely attributed to improved vegetation cover and soil conservation measures. The study also quantified the average annual growth rates of key gully characteristics, including frequency (2.87 km^2/year), length (1.66 m/year), density (0.12 km/km^2/year), dissection degree (0.01%/year), and width (0.04 m/year). Additionally, a strong power function relationship was identified between ephemeral gully volume and length, with an average gully volume development rate of 743.20 m^3/year.

These findings highlight the effectiveness of remote sensing and deep learning techniques in monitoring and modelling ephemeral gully erosion at a watershed scale.



Recognitionresults of the SegNet model in the Zhoutungou water shed in 2021. Ephemeral gully recognition results at (a) the water shed scale and (b) the sampling area.



Three spatial scale ephemeral gully monitoring methods.

The study provides an empirical model for assessing ephemeral gully volume and volume changes, offering valuable insights into the long-term dynamics of soil erosion. Understanding these processes is critical for developing targeted soil conservation strategies and improving land management practices on the Loess Plateau.

This research was supported by NNSFC, the National Key R&D Program of China and 111 Project of the Ministry of Education and the State Administration of Foreign Experts Affairs.

Understanding increased grain yield and water use efficiency by plastic mulch from water input to harvest index for dryland maize in China's Loess Plateau

Project team: Dr Hao Feng [4] (Project leader; nercwsi@vip.sina.com), Naijiang Wang[2,3,4], Xiaosheng Chu[5], Jinchao Li[4], Xiaoqi Luo[6], Dianyuan Ding[7], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]Shandong Agriculture and Engineering University, China; [3]Weifang University, Weifang, China; [4]Northwest A&F University, China; [5]Zhejiang University of Water Resources and Electric Power, China; [6]Southwest Forestry University, China; [7]Yangzhou University, China.

Dryland agriculture covers over half of China's cultivated land and is vital for national food security, especially in the Loess Plateau, which supports more than 100 million people. However, low grain yields due to water scarcity and climate stress make improving crop water use efficiency essential in this region.

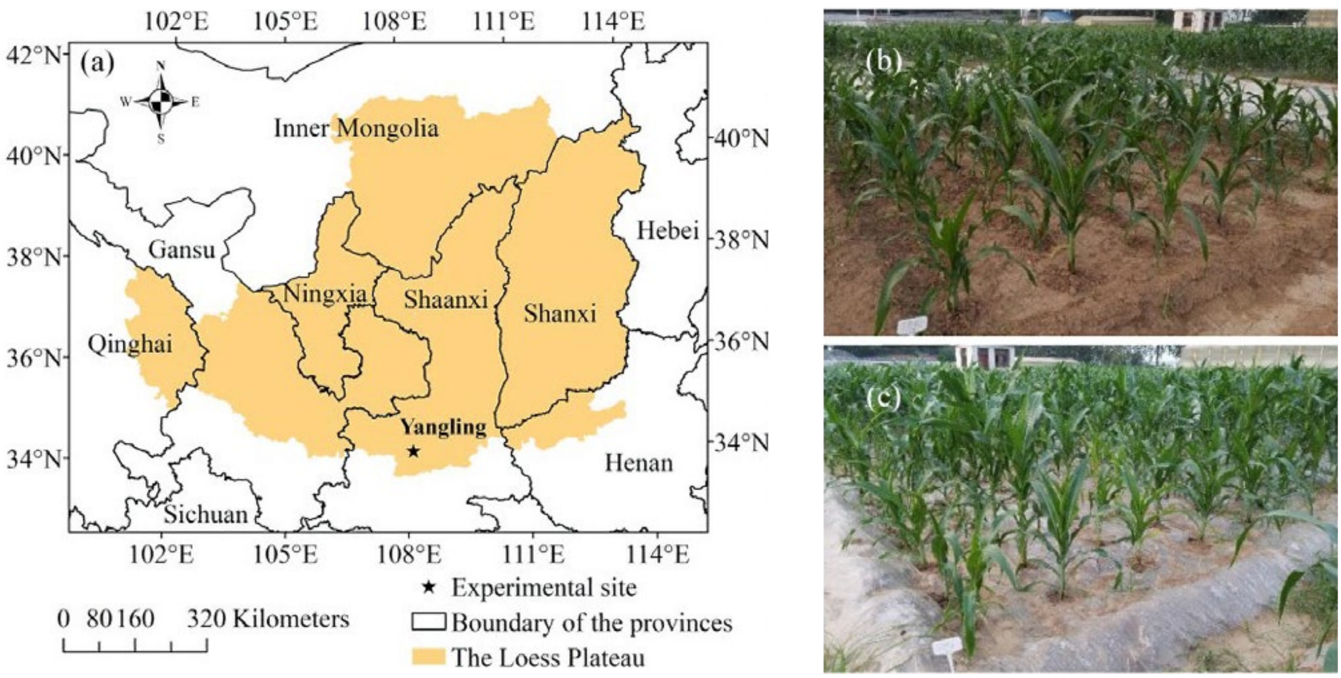
This study examines the impact of plastic mulch (PM) on water use, grain yield (GY), and water use efficiency (WUE) in dryland maize (Zea mays L.) on China's Loess Plateau. PM is widely used in arid and semi-arid regions, yet its effects on field water use dynamics remain unclear. A seven-year field experiment divided the maize growing season into early vegetative (EVS), late vegetative (LVS), and reproductive (RS) stages, assessing total water input (TWI), evapotranspiration to TWI ratio (ET/TWI), transpiration to ET ratio (T/ET), transpiration efficiency (TE), and harvest index (HI).

PM significantly altered water distribution across growth stages. TWILVS and TWIRS increased by 6.7% and 5.4%, respectively, while TWIEVS remained unchanged, indicating greater water availability during critical yield-forming periods. PM reduced ET/TWIEVS by 29.8% but increased ET/TWIRS by 23.9%, redistributing water use toward the reproductive stage. PM also enhanced T/ET across all stages, with an 83.3% increase in EVS and a 33.9% overall rise, promoting water use for biomass production. TE improved by 20.9% in LVS and 44.1% in RS, while HI remained stable, suggesting efficient biomass partitioning.

As a result, PM increased GY and WUE by 19.9% and 20.0%, respectively. The yield improvement was primarily attributed to increased water input and optimised transpiration during LVS and RS, which enhanced biomass accumulation and grain formation.

These findings underscore the role of PM in improving crop productivity by modifying water use patterns, particularly in water-limited environments. By redistributing water use toward critical growth stages and enhancing transpiration efficiency, PM presents a viable strategy for sustaining maize production under dryland conditions.

This research was jointly supported by the Project funded by China Postdoctoral Science Foundation, the National Key R&D Program of China, the NNSFC, and the 111 Project of the Ministry of Education and the State Administration of Foreign Experts Affairs.



Geographical location of the experimental site in China's Loess Plateau; (b) a planting system with no mulch in fields; and (c) a planting system with plastic mulch in fields

Film mulching can alleviate soil quality decrease and produce high maize yield under different irrigation strategies

Project team: Dr Hao Feng[2] (Project leader; nercwsi@vip.sina.com), Hackett Professor Kadambot H.M. Siddique[1], Hao Quan[2], Lihong Wu[2], Jiaming Sun[2], Tibin Zhang[3], Lianhai Wu[4], Bin Wang[5].

Collaborating organisations: [1]UWA, [2]Northwest A&F University, China; [3]Chinese Academy of Sciences and Ministry of Water Resources, China; [4]Sustainable Agriculture Sciences, Rothamsted Research, North Wyke, Okehampton, Devon, UK; [5]Wagga Wagga Agricultural Institute, NSW.

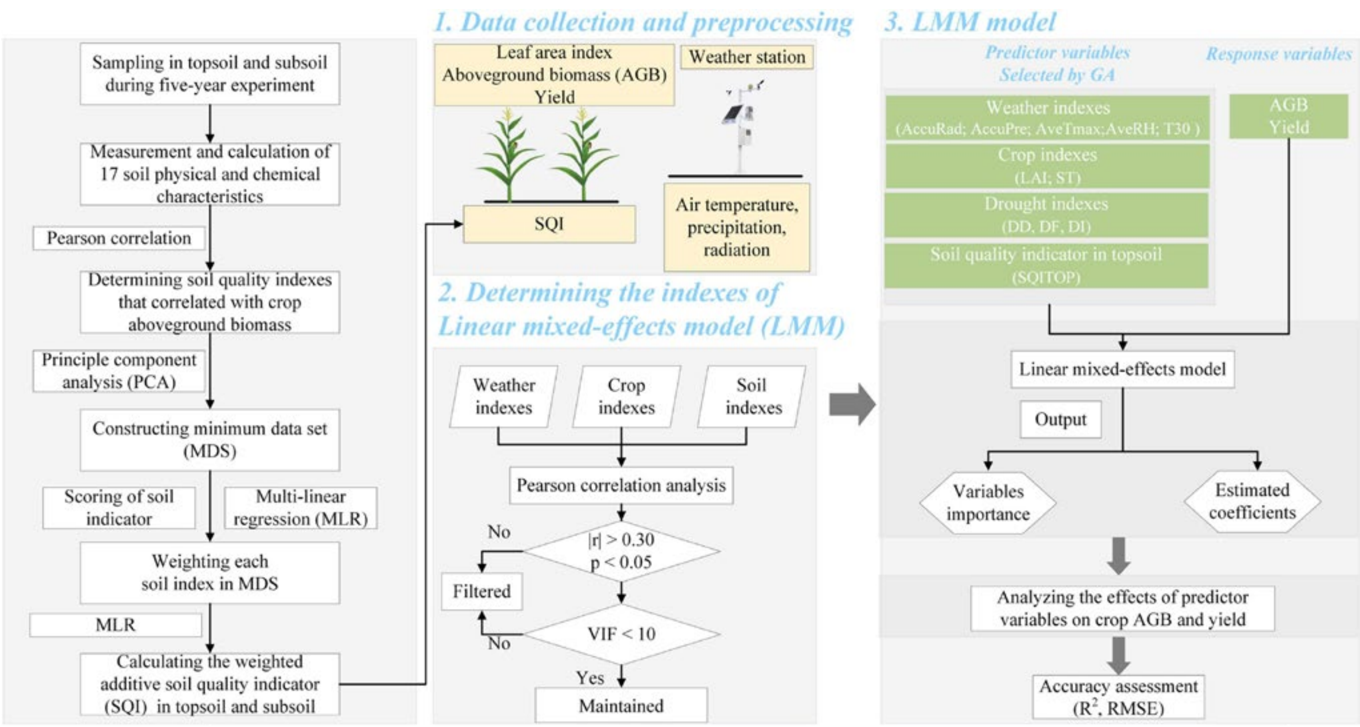
Plastic film mulching (PM) combined with irrigation is widely used in arid regions to enhance crop yields and improve water and nitrogen use efficiency. However, its long-term effects on soil quality and sustainability remain underexplored.

This study conducted a five-year field experiment in the Hetao Irrigation District (HID) in Northwestern China to assess the impact of different irrigation treatments combined with PM on soil quality and maize productivity. Researchers evaluated border irrigation without mulching (CK), CK with PM (BI_PM), and three drip irrigation treatments with PM at different soil matric potential thresholds: -10 kPa (HDI_PM), -30 kPa (MDI_PM), and -50 kPa (LDI_PM). A soil quality indicator (SQI) was developed using multiple soil properties to track changes over time and assess their influence on maize yield, irrigation water productivity (IWP), and partial factor productivity of nitrogen (PFPN).

Results showed that HDI_PM achieved the highest maize yield (15.77 t ha−1), IWP (3.73 kg m−3), and PFPN (63.18 kg kg−1), significantly outperforming the control treatment. Soil quality under HDI_PM remained stable over five years, while other treatments experienced a decline in SQI due to reductions in soil organic carbon (SOC), structural stability, and increases in soil salinity. A linear mixed-effects model indicated that low SQI (<0.43), along with elevated temperatures and drought, negatively affected yield.

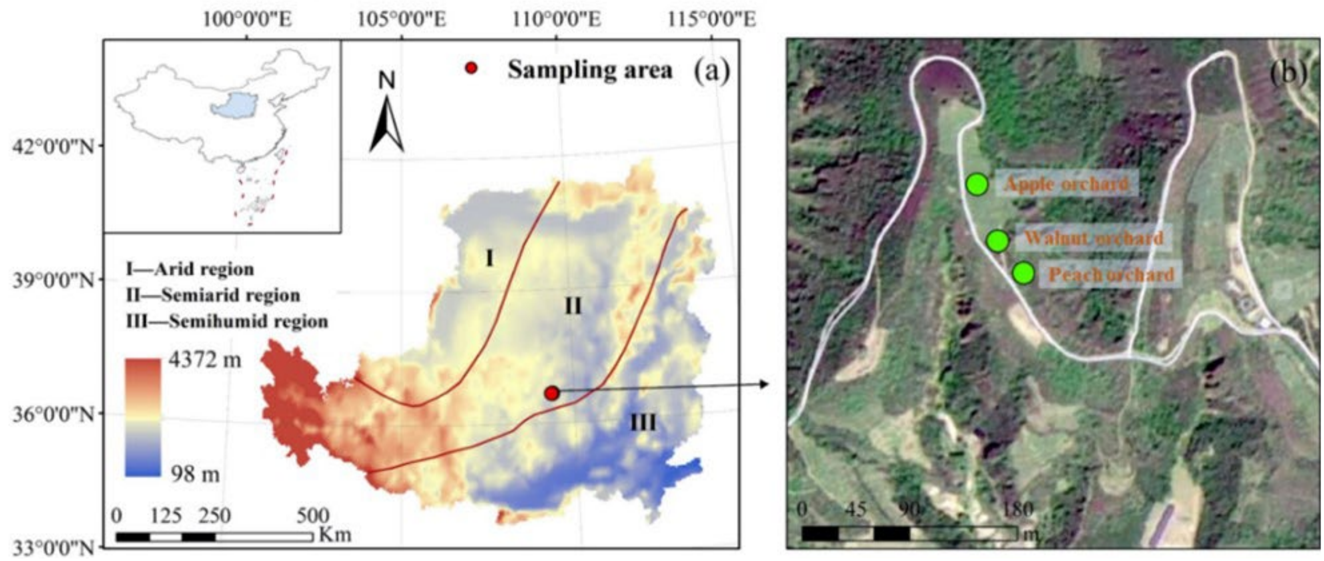
The findings highlight the effectiveness of HDI_PM in maintaining soil quality while maximizing productivity. However, long-term soil degradation under other treatments underscores the need for improved agronomic practices, such as incorporating organic matter and green manure, to sustain soil fertility.

This research is supported by the National Key R&D Program of China and NNSFC.



Overview of the workflow to develop soil quality indicator (SQI) and the linear mixed-effects model (LMM) to estimate maize aboveground biomass and yield based on weather, crop, and soil characteristics. GA: genetic algorithm, R^2: coefficient of determination, RMSE: root mean squared error.

Transpiration and water use strategies of three economic tree species in a semi-arid afforestation region



Location of the study area (a) and the sampling sites of the three orchards (b).

Project team: Hao Feng[2,6] (Project leader; nercwsi@vip.sina.com), Yongcai Lou[2] (Project leader; lyc4026@126.com), Wenjie Wu[1,2], Yue Li[2], Kiril Manevski[3,4], Mathias Neumann Andersen[3,4], Bingcheng Si[5], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]Aarhus University, Tjele, Denmark; [4]Sino-Danish Center for Education and Research, China; [5]University of Saskatchewan, Canada; [6]Chinese Academy of Sciences and Ministry of Water Resources, China.

Understanding transpiration and water use strategies is crucial for managing orchards in semi-arid regions.

This study examined the sap flow dynamics of peach (*Prunus persica*), walnut (*Juglans regia* L.), and apple (*Malus pumila*) trees over two years on the Loess Plateau of China, using the thermal dissipation probe method to track variations in water use.

Researchers measured transpiration and canopy conductance while monitoring meteorological conditions, soil water content, and leaf area index.

On sunny days, all three species exhibited single-peak sap flux curves, but peak times varied. Peach and apple trees reached their peak sap flux earlier than walnut trees, reflecting species-specific differences in water uptake. Tr and gc followed each species' phenology, with environmental and physiological drivers differing across species.

Solar radiation was the dominant factor affecting Tr in peach and apple trees, while vapor pressure deficit primarily controlled Tr in walnut trees. At a monthly scale, LAI positively correlated with Tr in peach and walnut trees but had little effect on apple trees.

Water use strategies also varied. Peach and apple trees demonstrated higher stomatal sensitivity than walnut trees, indicating stronger stomatal regulation and more conservative water use. These differences suggest that tree species adopt distinct strategies to cope with water limitations in semi-arid regions.

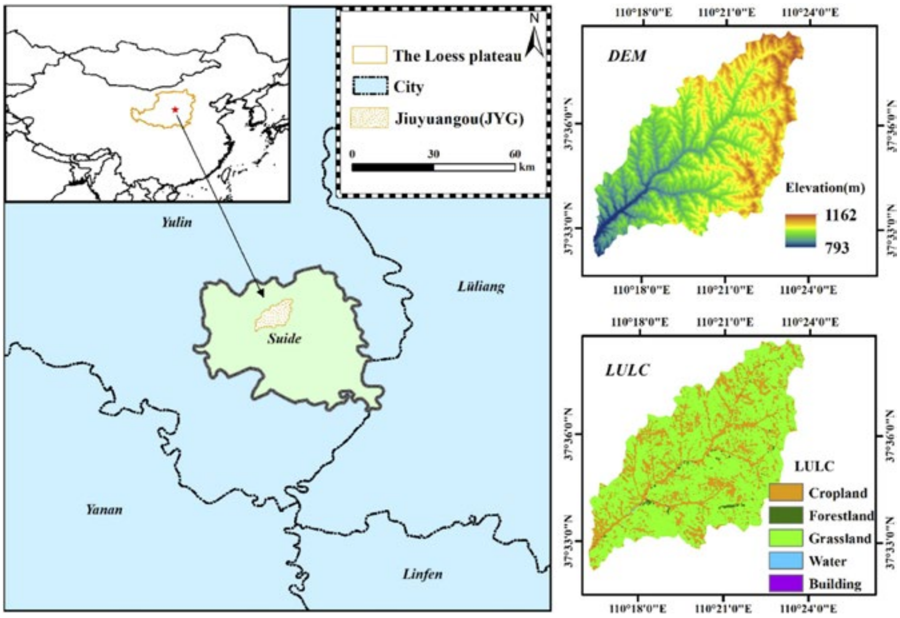
The findings highlight how phenology influences transpiration patterns and provide valuable insights for orchard management. Understanding these variations can help optimise irrigation strategies, improve water efficiency, and support sustainable fruit production in water-limited environments.

This research is supported by NNSFC, the Fundamental Research Funds for the Central Universities, National Key R&D Program of China, and the Natural Science Foundation of Hunan Province.

Soil erosion projection and response to changed climate and land use and land cover on the Loess Plateau

Project team: Professor Shufang Wu[2] (Project leader; wsfjs@163.com), Biao Zhang[1,2], Jialong Guo[1,2], Haiyan Fang[2,3], Hao Feng[4], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]Chinese Academy of Sciences, China; [4]University of Chinese Academy of Sciences, China; [5]Institute of Soil and Water Conservation, Chinese Academy of Sciences & Ministry of Water Resources, China.



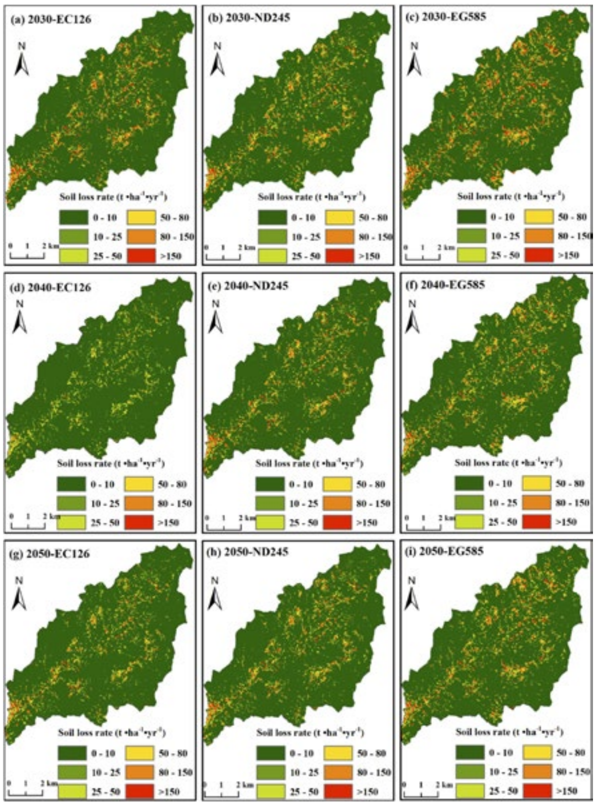
Location, elevation, and LULC of the Jiuyuangou watershed (JYG).

The Grain for Green Project has significantly transformed land use and land cover (LULC), climate, and soil erosion rates on the Loess Plateau, China.

This study evaluates historical and projected soil erosion in the Jiuyuangou watershed using the Revised Universal Soil Loss Equation model coupled with the Future Land Use Simulation model and climate projections from CMIP6. By integrating qualitative and quantitative analysis, the study assesses the impact of LULC and climate change on soil erosion.

Results indicate a significant decline in soil loss rates from 64.95 t ha^{-1}·yr^{-1} in 1995 to 4.52 t ha^{-1}·yr^{-1} in 2020, coinciding with an increase in forest and grass cover from 33.4% to 74.1%. The trend of converting cropland to forest and grass is expected to continue, yet soil erosion is projected to rise between 2030 and 2050 due to increased rainfall erosivity and suboptimal LULC allocation. Scenarios prioritising ecological protection are predicted to mitigate erosion more effectively than others.

Attribution analysis reveals that check dam construction played a critical role in reducing erosion from 1995 to 2005, while afforestation from 2005 to 2020 accounted for 64.6% of the overall reduction. However, future soil erosion rates will likely be more influenced by climate factors than LULC.



Distribution of soil erosion rates for future period in the Jiuyuangou watershed (EC126: Ecological Conservation Pathway and SSP126, ND245: Natural Development Pathway and SSP245, EG585: Economic Growth Pathway and SSP585).

The study underscores the importance of sustainable land management strategies, particularly for abandoned croplands and sediment retention structures, to counteract the expected rise in erosive rainfall.

This research is supported by NNSFC, and the National Key R&D Program of China, and Evolution of water system and regulation mechanisms on agricultural non-point sources in the upper reaches of Red River Basin.

Optimizing sowing date to mitigate loss of growing degree days and enhance crop water productivity of groundwater-irrigated spring maize

Project team: Professor Qiliang Yang[2] (Project leader; yangqilianglovena@163.com), Lifeng Zhou[2], Xinlong Han[2], Hao Feng[3], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]Kunming University of Science and Technology, China; [3]Chinese Academy of Sciences and Ministry of Water Resources, China.

Groundwater irrigation (GWI) reduces soil temperature, prolongs crop growth duration, and increases water consumption, necessitating cost-effective mitigation strategies.

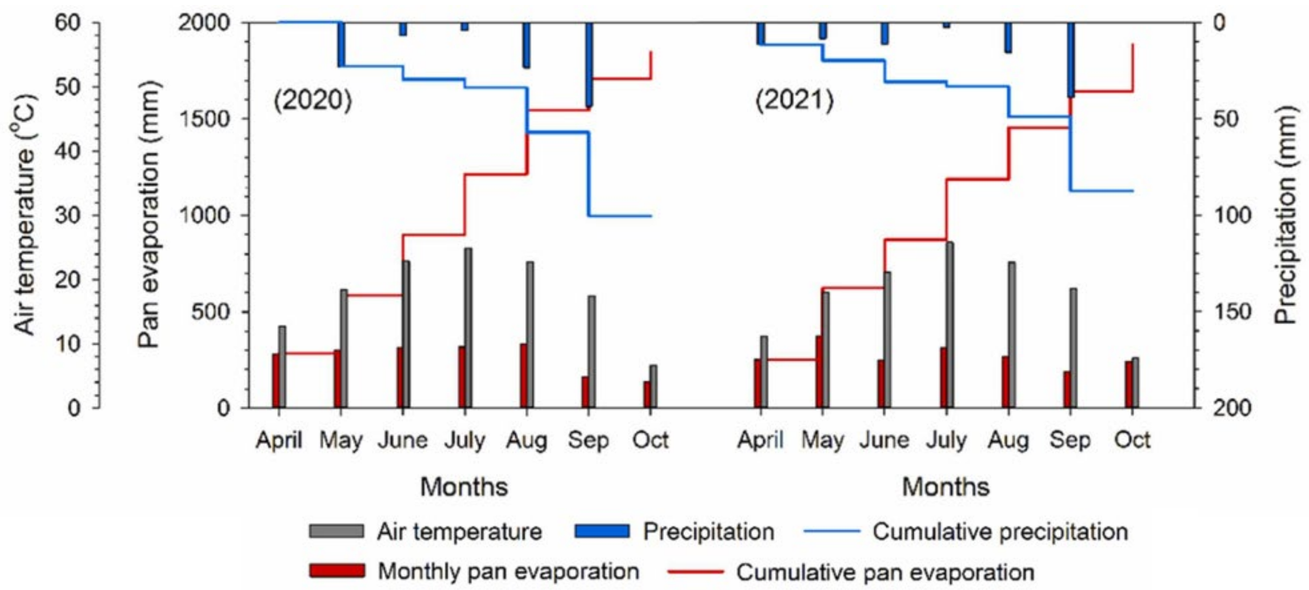
This study assessed five sowing dates for spring maize under GWI: April 20 (GW420), April 25 (GW425), April 30 (GW430), May 5 (GW505), and May 10 (GW510), with surface water irrigation (SWI) on April 20 (SW420) as the control. Key parameters included soil temperature at 5 cm depth (T5), soil-temperature-calculated growing degree days (GDDs), actual crop evapotranspiration (ETc-act), leaf area index (LAI), grain filling, grain yield, and crop water productivity (WPc).

Compared to SW420, GW420 decreased daily maximum T5 by 1.8°C ($P<0.05$) and daily average GDDs accumulation by 5.9%, extending growth duration by 7.8 days and increasing ETc-act by 33.2 mm. It also delayed LAI growth, reduced maximum grain-filling rate (Gmax) and its weight (Wmax), lowering mean LAI (LAIave) by 8.7%, grain yield by 6.7%, and WPc by 10.2% ($P<0.05$). Late sowing compensated for GDDs loss, with GW505 and GW510 recording the highest daily average GDDs accumulation (21.3°C d–1), followed by SW420 and GW430 (20.2–20.3°C d–1), while GW420 and GW425 had the lowest (19.1–19.4°C d–1). Late sowing also shortened growth duration and reduced ETc-act, with GW510 showing a 13.9-day shorter growth period and GW425, GW430, GW505, and GW510 reducing ETc-act by 30.6, 36.0, 57.6, and 70.2 mm, respectively, compared to GW420.

Moderately late sowing (GW430) enhanced Gmax and maintained the active grain-filling period (Tagp). WPc increased by 7.9%, 16.8%, 17.4%, and 17.2% in GW425, GW430, GW505, and GW510 ($P<0.05$), respectively, compared to GW420. While grain yields in GW430 and SW420 did not significantly differ, GW430 achieved higher WPc, suggesting that moderately late sowing effectively offsets yield and WPc declines in GWI maize.

Entropy-TOPSIS analysis revealed that Tagp, Gmax, ETc-act, grain yield, and WPc under GW430 had the highest comprehensive scores, indicating that GW430 is the optimal sowing date for GWI maize in arid regions of northwest China. This study provides a cost-effective method to mitigate GWI-induced GDDs losses and improve WPc for GWI maize.

This research is supported by NNSFC, the Yunnan Fundamental Research Projects, and the Yunnan Provincial Field Scientific Observation and Research Station on Water-Soil-Crop System in Seasonal Arid Region.



Air temperature, precipitation, and evaporation during the 2020 and 2021 spring maize growing seasons at the experimental site. Columns represent monthly average values, and lines represent monthly cumulative values.

Concurrent drought threaten wheat and maize production and widen crop yield gaps in the future

Project team: Associate Professor Yi Li[9] (Project leader; liyi@nwafu.edu.cn), Miaolei Hou[9], Asim Biswas[2], Xinguo Chen [9], Lulu Xie[9], Deli Liu[3,4], Linchao Li[5], Hao Feng[5], Shufang Wu[5], Yusuke Satoh[6,7], Alim Pulatov[8], Hackett Professor Kadambot H.M. Siddique[1].

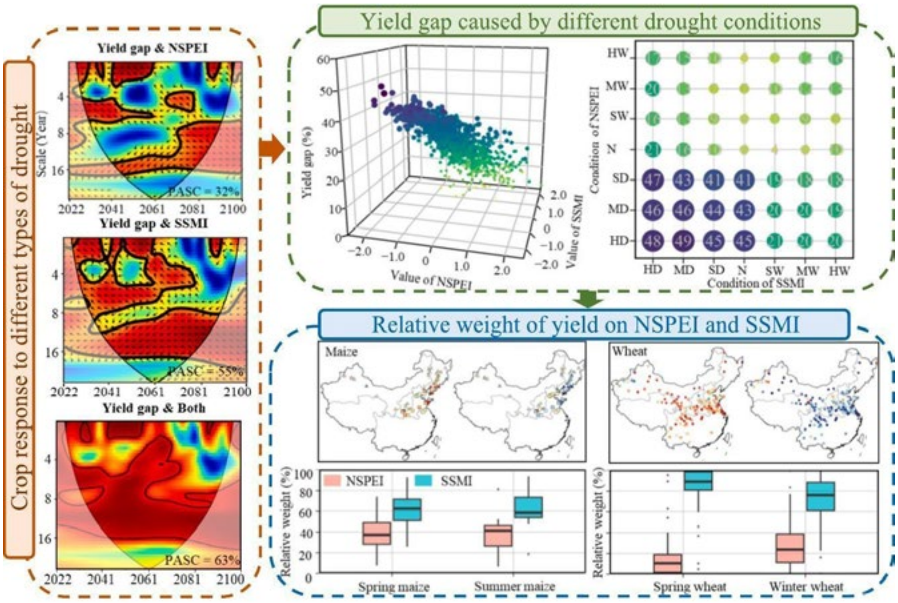
Collaborating organisations: [1]UWA; [2]University of Guelph, Canada; [3]NSW Department of Primary Industries; [4]University of New South Wales; [5]State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, China; [6]National Institute for Environmental Studies, Tsukuba, Japan; [7]International Institute for Applied Systems Analysis, Austria; [8]National Research University, Uzbekistan; [9]Northwest A&F University, China.

The growing threat of food insecurity, driven by climate change, economic instability, and geopolitical tensions, is being compounded by the increasing frequency and severity of droughts.

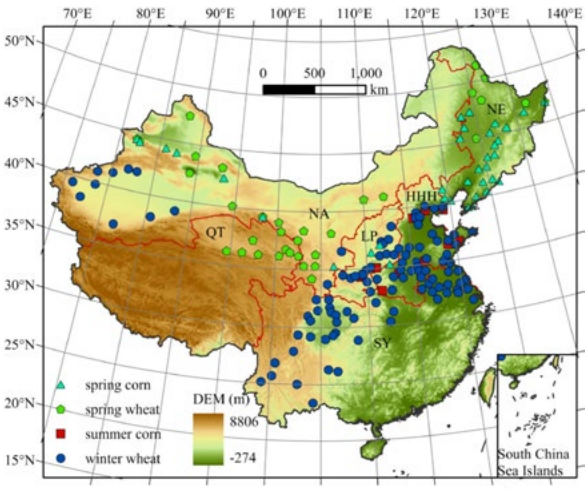
This study examines how wheat and maize, two key global crops, respond to different types of droughts, particularly focusing on the yield gaps caused by concurrent meteorological and agricultural droughts.

It highlights the increasing vulnerability of crops to concurrent drought, which results in larger yield gaps compared to single-type drought events. Projections from 2022 to 2100 show that drought-induced yield losses could increase by 2-30% when both meteorological and agricultural drought occur together. Wheat is more severely affected than maize, with yield reductions ranging from 5-50% and 0-35%, respectively. The western regions are predicted to experience more significant impacts than the eastern regions.

Additionally, the study introduces a vine Copula framework and cross-wavelet methods to quantify the yield gaps, further revealing that soil moisture (measured by the Standardized Soil Moisture Index, SSMI) plays a more critical role in drought resilience than the Standardized Precipitation Evapotranspiration Index (NSPEI). Under future SSP5-8.5 climate scenarios, crops are projected to show a higher dependence on SSMI (51-99%) than NSPEI (26-59%).



Graphic Abstract.



The elevation, division of agricultural regions and distribution of 185 studied agri-meteorological sites. The agricultural sub-regions and crops grown therein are: Northeast Plain (NE, spring wheat and spring maize), Loess Plateau (LP, spring maize, summer maize and winter wheat), Huang-Huai-Hai plain (HHH, summer maize and winter wheat), Northern Arid and Semi-Arid Region (NA, spring maize, spring wheat and winter wheat), Qinghai-Tibet Plateau (QT, spring wheat) and South of Yangtze River Region (SY, winter wheat).

These findings provide a comprehensive analysis of the significant impact of concurrent drought on wheat and maize yield gaps, which are critical for global food security. Future concurrent drought will have a serious impact on crop yields, making accurate drought monitoring and early warning essential. Given the different responses of wheat and maize to different drought indices, it is suggested that preventive measures should be developed for the different crops. In addition, the research also provides practical inspiration for the development of a comprehensive drought index for monitoring agricultural drought.

This research is supported by NNSFC, and the Natural Science Foundation of Shenzhen.

Aerated irrigation improves soil gross nitrogen transformations in greenhouse tomato: insights from a 15N-tracing study

Project team: Associate Professor Yadan Du[2] (Project leader; dyd123027@163.com), Chuandong Tan[2], Xiaotao Hu[2], Xiaoyan Li[2], Yuming Wang[2], Tinglin Yan[2], Jinbo Zhang[2], Wenquan Niu[2], Xiaobo Gu[2], Professor Christoph Müller[3,4], Hackett Professor Kadambot H.M. Siddique[1].

Collaborating organisations: [1]UWA; [2]Northwest A&F University, China; [3]Justus-Liebig University Giessen, Germany; [4]University College Dublin, Ireland.

This research emphasizes that AI, particularly with organic fertiliser integration, enhances N availability, accelerates organic N turnover, and improves N retention, leading to better crop yields.

Nitrogen is vital for plant growth but often limited in availability, as most soil nitrogen is in organic forms that require microbial conversion into inorganic forms for plant uptake. Aerated irrigation (AI), by enhancing soil oxygen levels, may influence nitrogen cycling and improve fertiliser efficiency and crop yields, making it crucial to understand soil N transformations under this practice.

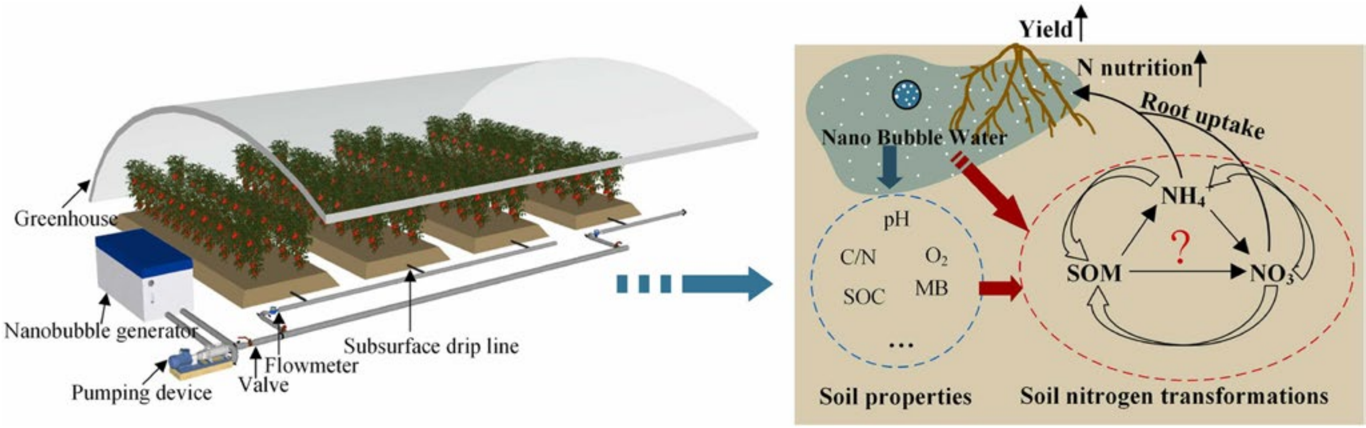
This study investigates the impact of AI on soil nitrogen (N) dynamics and crop yield, specifically in greenhouse tomato production. Using a 15N tracing incubation experiment, the research explores the effects of different fertilization strategies under AI, including chemical fertiliser (AINPK), organic fertiliser (AIOM), and a combination of both (AINPK+OM), in comparison to traditional drip irrigation (NPK). All treatments received an equivalent N input of 150 kg N ha–1.

The results indicate that AI significantly enhanced soil nitrogen availability and crop yield. The AINPK treatment increased tomato yield by 12.42%, while also elevating gross N mineralization by 2.58-fold and gross nitrification by 1.27-fold compared to the NPK treatment. The addition of organic fertilisers (AIOM and AINPK+OM) further improved nitrogen transformations, with yield increases ranging from 12.34% to 18.74%. Additionally, AIOM exhibited the highest NH4+ immobilization rates, 1.16–1.26 times higher than the other treatments, thereby enhancing nitrogen retention.

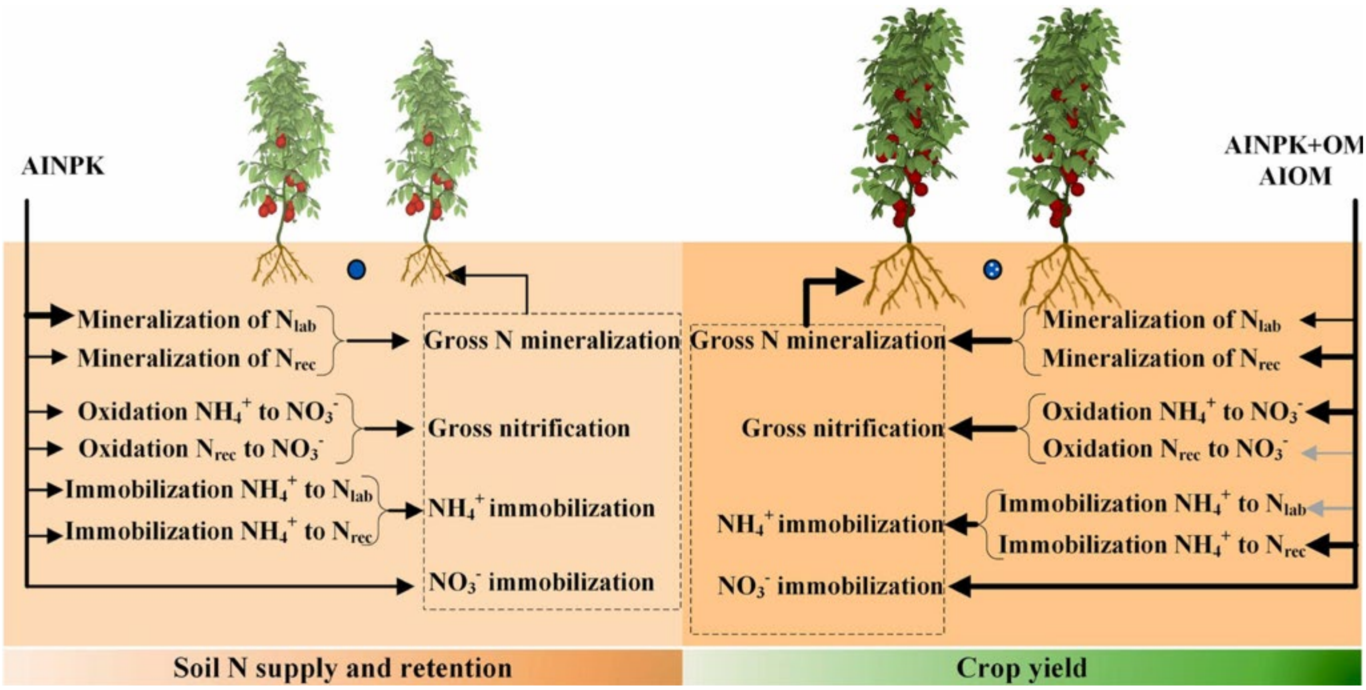
AI also promoted faster organic N turnover, reducing the turnover time of organic N compared to traditional drip irrigation. The study found that the AINPK+OM and AIOM treatments increased inorganic N retention capacity and reduced nitrogen losses, mitigating the environmental risks associated with excess nitrate leaching. The enhanced N mineralization and nitrification rates under AI contribute to more efficient nitrogen use in agricultural systems.

This research emphasizes that AI, particularly with organic fertiliser integration, enhances N availability, accelerates organic N turnover, and improves N retention, leading to better crop yields. The findings suggest that AI-based systems with organic fertilization can be recommended for optimizing fertiliser management and promoting sustainable agricultural practices in greenhouse tomato cultivation.

This research is supported by the National Natural Science Foundation of China for Young Scholars, the Key Research and Development Program of Shaanxi Province, and the China Postdoctoral Science Foundation.



Schematic layout of the tomato plantation with AI system and scientific problems.



Schematic illustration of soil N transformations after aerated irrigation and different fertiliser applications. Notes: Arrow width visualizes the magnitude of the increase in N conversion rate, while the gray arrow denotes its reduction.

Fresh Pink Lady apples.

4

Food Quality and Human Health

Health attributes of foods is an important driver for food choices. Consumption of healthy foods is the cornerstone of efforts to improve diet quality in populations. Higher intake of plant foods is associated with lower risk of many chronic diseases including diabetes and cardiovascular disease.

The aim of this theme is to develop healthier foods and food ingredients that can make a positive contribution to human health and the Australian economy. The development and validation of healthy foods that meet consumer desires is an exciting challenge for the Australian agri-food industries. Critical for achieving these outcomes is the establishment of cross-disciplinary collaborations and collaboration with relevant industries. This research theme integrates the complementary skills, knowledge and activities across disciplines and organisations that will enable increased success.

The research is leading towards the development of a collection of healthy functional foods and ingredients, as well as improved processes for their 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.

Theme Leaders

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Master student Dilini Silva.

Screening of apple (Malus domestica) accessions of the Australian National Apple Breeding Program for scab resistance using trait-linked molecular markers

Project team: Dr Sultan Mia[1,2] (Project leader; sultan.mia@uwa.edu.au), Associate Professor Michael Considine[1,2], Dilini Silva[1,2].

Collaborating organisations: [1]UWA; [2]DPIRD.

Apple scab is a serious disease that affects apple (Malus domestica) cultivation worldwide. It is caused by the pathogenic fungus Venturia inaequalis (V. inaequalis) and results in lower fruit quality and commercial losses. Although the disease has traditionally been controlled with fungicides, which have adverse impact on the environment, including contributing to the formation of resistant strains of the pathogen. Developing scab-resistant apple varieties is a feasible strategy, specifically using marker-assisted selection (MAS).

The "Australian National Apple Breeding Program" (ANABP) maintains a germplasm repository comprised of a rich collection of apple accessions at the "Horticultural Research Institute" situated at Manjimup, Western Australia. However, its genetic potential for scab resistance has yet to be explored.

Postgraduate student Dilini Silva performed this study to screen these accessions for scab resistance to identify potential parental accessions which could be exploited in the crossing program to integrate scab resistance with desirable fruit characteristics. Young leaf samples were collected from the 192 accessions of the repository.

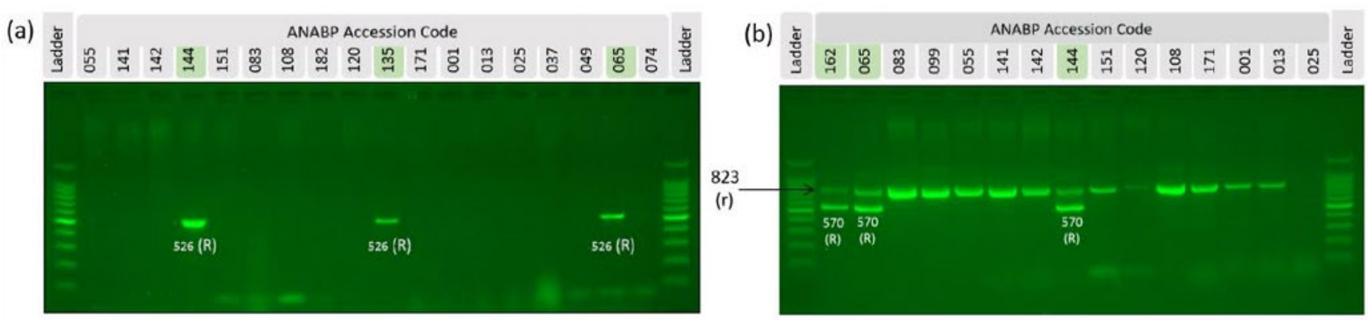
The subsequent procedure includes sample processing, DNA extraction, DNA amplification by PCR, visualising through agarose gel electrophoresis and electropherograms, allele calling and genotype profiling through Geldoc and GeneMarker app.

Among 192 screened ANABP accessions, five (ANABP_accession_065, ANABP_accession_135, ANABP_accession_144, ANABP_accession_162, and ANABP_accession_173) were found to be resistant possessing Rvi6. In addition, the FMACH_VM3 marker indicated a potential association between ANABP_accession_083 and the Rvi5 resistance gene; however, additional confirmation is required. Other resistance-associated markers (OPB18, AD13, KO8, and CH02c02a) failed to identify any additional resistant accessions among the studied accessions.

In the second experiment, seedlings from the cross between 'Cripps Pink' and ANABP_accession_162 were screened using disease resistance and fruit quality markers. The 'Cripps Pink' is a proven commercial cultivar with good fruit quality but susceptible to scab disease, whereas ANABP_accession_162 was recognized in the prior experiment as a scab resistant accession. 27 seedlings from this cross were found carrying scab resistance locus, and 15 of them also exhibited genotype for better firmness and red skin colour. Ten individuals were discovered as potential parents for future breeding due to their favourable combinations of preferred fruit quality traits and disease resistance. The ANABP intends to phenotype the selected parents and these progenies by artificial inoculation to assess the actual resistance.

The outcome of the research is vital for the strategic development of novel apple varieties exhibiting robust resistance to V. inaequalis, thereby enhancing agricultural sustainability and economic stability in the industry.

This research is supported by DPIRD, CRC SAAFE and UWA.



Gel electrophoresis profile of 15 apple f accessions that were tested with marker AL07. ANABP_accession_162, ANABP_accession_065 and ANABP_accession_144) show 570bp and 823bp, indicating heterozygous resistance. The ladder used is 100 bp Bioline Hyper Ladder. Agarose gel of 1.5%, run at 140V for 35 minutes.

Phytochemical analysis and bioactivity profiling of Clover honeys

Project team: Associate Professor Dr Cornelia Locher[1] (Project leader; connie.locher@uwa.edu.au), Dr Kevin Joseph Foster[1], Professor Lee Yong Lim[1], Associate Professor Dr Katherine Hammer[1].

Collaborating organisations: [1]UWA.

This study is the first to report on some phytochemical (i.e. phytoestrogen, total phenolic content, sugar profile) and physicochemical characteristics (i.e. pH, colour, moisture content) and in vitro antioxidant activity (FRAP, DPPH) of monofloral clover honeys (unripe and mature).

The production of monofloral clover honey was initiated with the seedlings of clover cultivars, two red clover (Trifolium pratense) cultivars (NSE and NFE), a purple clover (T. purpureum) cultivar, Electra and a sainfoin clover (Onobrychis viciifolia) cultivar, Othello followed by moving them into their designated plot inside shade house enclosure at UWA Shenton Park Field Station and installation of nucleus beehive. This approach allowed to produce monofloral honeys and therefore to derive typical phytochemical characteristics for each clover honey without potential interference from co-flowering species as might be the case for wild-harvested honeys.

A special focus was given on the presence of oestrogenic compounds in different clover flower nectar samples, in bee-deposited nectars collected from hive combs (unripe honey) and in mature honeys harvested from the same hives. A total of eight isoflavones, four of them non-glycosidic (methylated form- biochanin A & formononetin and demethylated form- genistein & daidzein) and other glycosidic (sissotrin, ononin, genistin and daidzin), were targeted for identification and quantification in this study using high-performance thin-layer chromatography (HPTLC). Leaves and flower bracts of the clover samples were also investigated.

Monofloral clover honey collection.

Red clover in enclosed shadehouse.

Different isoflavone profiles were found across the clover species and also in the different samples collected from each species indicating that, most likely due to the activity of honeybee (Apis mellifera) salivary enzymes, biochemical conversions take place when these bioactive compounds transition from flower nectar into mature honey.

While research into the phytochemical composition of various honeys and their associated bioactivities is growing, there is a scarcity in published information on clover honeys which created the impetus for this study to investigate chemical composition and bioactivities of different clover honeys to explore potential future opportunities for both the pharmaceutical and apiculture industry.

While all clover honeys were found to be slightly more acidic and have a slightly higher water content, they exhibited similar fructose and glucose ratios compared to most of the investigated Western Australia (WA) honeys. The clover honeys were also found to have a medium strength antioxidant activity which was measured using the 2,2-diphenyl-1-picrylhydrazyl and Ferric Reducing Antioxidant Power assays and a moderate amount of phenolic constituents (measured as total phenolic content) when compared to other WA honeys.

This research is supported by UWA.

Study on the effect of high temperature on bud burst and energy reserves in grapevine.

The function of light spectrum in climate plasticity of grapevine

Project team: Associate Professor Michael Considine[1] (Project leader; michael.considine@uwa.edu.au), Noor Shaik[1], Hackett Professor Kadambot H.M. Siddique[1], Dr Aneta Ivanova[1], Wenyi Xu[1].

Collaborating organisations: [1]UWA.

Grapevine is the most economically important fruit crop in Australia and worldwide. Grapevine is a woody perennial plant with historical records of production and phenology that was domesticated in a Mediterranean climate and typically displays a deciduous habit. Climate change has the negative effect on plant growth due to the damaging effect of high temperature on physiological, biochemical, and gene regulation pathways, altering plant development and ultimately reducing yield. Climate Atlas project forecasts that there will be an increase in temperature across all regions with an average increase of 1.2°C by 2050 and 2.8°C by 2090. This predicts that these regions are prone to heatwaves and will be arid.

Higher plants calibrate developmental and reproductive transitions with the predictable environmental cues of light and temperature. Plants perceive changes in light availability and spectrum through families of photoreceptors. These photoreceptors include phytochromes (PHY), cryptochromes (CRYs), phototropins (PHOTs), and UV RESISTANCE LOCUS 8 (UVR8), which are primarily responsible for perceiving red (600-750nm), blue (390-500nm), and ultraviolet-B (UV-B) light (280-320nm), respectively.

Shading (low R/FR and low blue light) results in the inactivation of photoreceptors such as PHYB, CRYs, PHOTs and UVR8 which leads to increased activity of two key regulatory players: PIF's (growth-promoting transcription factors) and the E3 ligase complex CONSTITUTIVELY PHOTOMORPHOGENIC 1 (COP1) and SUPPRESSOR OF PHYA-105 (SPA1), which control the ubiquitination and degradation of the growth-inhibiting transcription factor HY5. Enhanced abundance and activity of PIFs, particularly PIF7, induces auxin biosynthesis and the expression of growth-promoting genes in low R/FR ratios.

In Grapevine, bud burst is a key developmental transition requiring a careful coordination of energy availability and developmental processes. Physiological studies suggest that the shade-avoidance phenotype in grapevine is due to low levels of blue light, rather than low levels of red light.

Temperature is a key environmental factor driving bud burst in grapevine. Sink strength is regulated primarily by the activity of sugar, hormone transport, and metabolism. In Rosa species, light is required to activate expression and activity of vaculoar invertase (VIN) to enable sugar mobilisation and bud outgrowth. Whereas in grapevine, VIN gene expression is not light regulated, but was strongly influenced by temperature. Higher temperatures accelerated bud burst and enhanced shoot length, leaf/node numbers, and lateral leaf outgrowth.

Study on the effect of high temperature and light quality on vegetative plant growth and date of flowering.

This suggests that young shoots are weak sink due to utilisation of reserves by the vegetative parts developed. These studies collectively raise important questions about Grapevine development, revealing that high temperature affect growth, the molecular mechanisms underlying their impact on shoot elongation and sink strength remain poorly understood.

In Australia, temperatures can surpass 40°C for prolonged periods affecting carbon assimilation and thus sugar accumulation in grapes. At present, there is a lack of knowledge of how to adapt production practices or develop new germplasm that will enable sustainability of the grapevine industries under future scenarios.

This research is supported by CRC-NA, DPIRD and Fresh Produce Group.

Characterising Cripps Pink apple and its mutants using advanced genetic and genomic tools

Project team: Hackett Professor Kadambot H.M. Siddique[1] (Project leader; kadambot.siddique@uwa.edu.au) , Md Golam Azam[1], Dr Sultan Mia[2], Associate Professor Michael Considine[1].

Collaborating organisations: [1]UWA; [2]DPIRD.

Cripps Pink is one of the most prominent apple cultivars globally, renowned for its crisp texture, vivid pink colour, delectable and tangy flavour.

Marketed under the trade name Pink Lady™, it is the most popular cultivar in Australia. Several spontaneous mutants (bud or limb sports) of Cripps Pink including Lady Laura, Rosy Glow, Lady in Red, PLMAS98, Ruby Pink, PLBAR B1, PLFOG99 (Pink Belle), Barnsby and Yellow Cripps Pink have been patented, which exhibit distinct characteristics in terms of fruit skin colour, maturity, and canopy structure.

To date, these mutants have only been characterized morphologically and physiologically. No comparative genetic and genomic studies have been conducted on them yet. Understanding of the genetic, and genomic determinants underlying the phenotypic differences among them is crucial for the future development of trait-specific apple breeding.

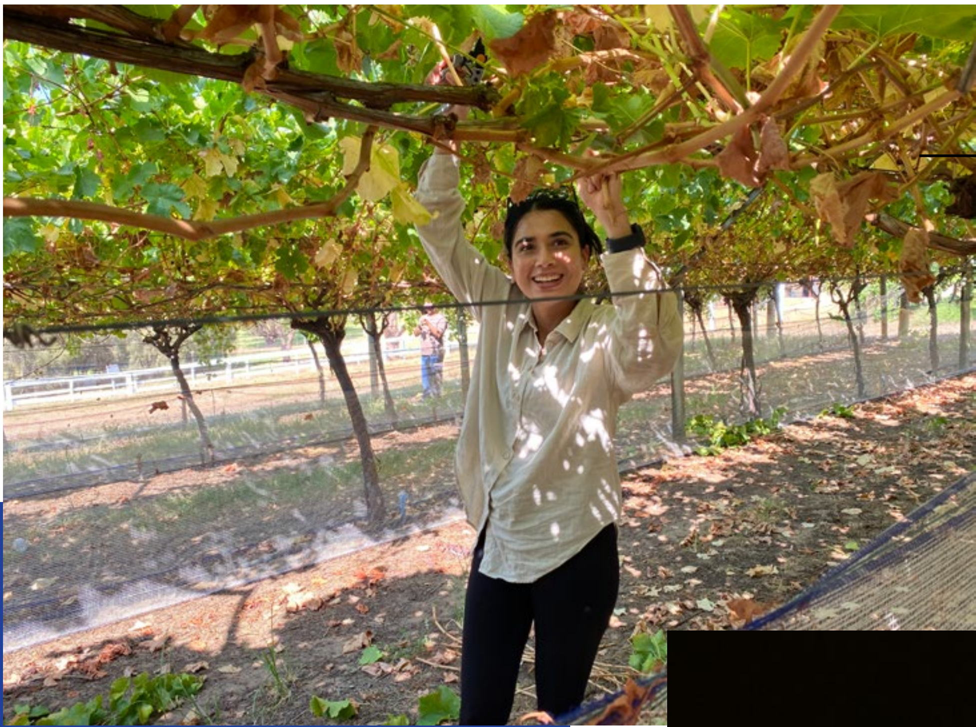
This project aims to conduct a comprehensive genetic and genomic characterisation to elucidate the distinctiveness of Cripps Pink and the factors that influence the variations of these mutations. Whole- genome and transcriptome sequencing using the latest technology will be employed. Comparative genetic and genomics studies will identify genomic regions responsible for the variations among these cultivars and mutants, laying the groundwork for developing trait-based DNA markers for marker-assisted selection.

This approach will potentially enhance selection from promising crosses at early seedling stage, ultimately shortening the time required to breed new apple varieties.

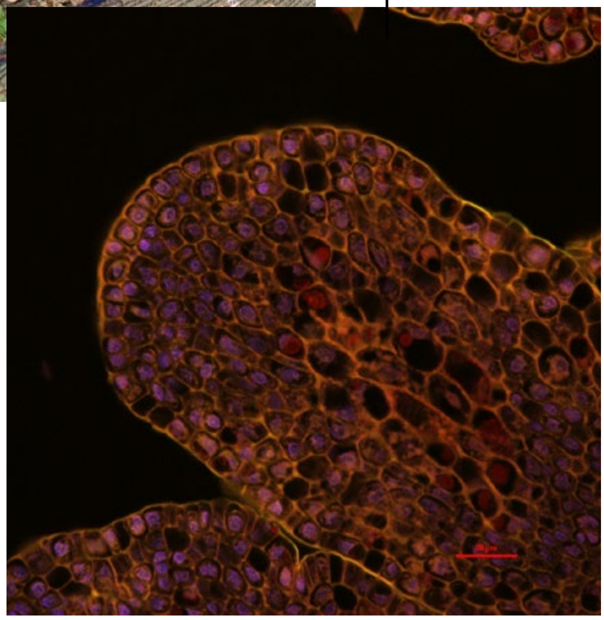
This research is supported by UWA international fee scholarship, Australian Government Research Training Program Stipend Scholarship and John Cripps Horticulture HDR Top-Up Scholarship.

Top image: PhD student Golam Azam (right) collecting Leaf samples from the orchard of MHRI, DPIRD, Manjimup with DPIRD staff (from left Dr Sultan Mia & Kevin Lacey).

Bottom image: The fruits of original Cripps Pink apple (CP) and its mutants including Rosy Glow, Lady in Red, Ruby Pink, Yellow Cripps Pink (YCP) and Barnsby at mid developmental stage.



Field sampling of grapevine canes var. Sweet Globe following harvest in Swan Valley.



High-magnification confocal image of an inflorescence primordium, stained with Safranin O and DAPI. Lignified cell walls fluoresce orange-red, and nuclei appear blue. Captured at 60x magnification using excitation wavelengths at 358 nm, 488 nm, and 568 nm.

Metabolic regulation of inflorescence development and fate in grapevine

Project team: Associate Professor Michael Considine[1] (Project leader; michael.considine@uwa.edu.au), Pragya Poudel[1], Hackett Professor Kadambot H.M. Siddique[1], Professor John A. Considine[1], Dr Aneta Ivanova[1].

Collaborating organisations: [1]UWA.

Table grapes are Australia's most valuable horticultural commodity; however, limited seasonal availability makes Australia a net importer for several months of the year. The opportunity to fill this gap by expanding production in northern Australia is currently limited by poor yields, which are associated with warmer temperatures during critical development periods.

This research aims to elucidate the effect of elevated temperatures on inflorescence initiation and development in grapevine. Our study employs anatomical, histological, biochemical, and genetic approaches to determine the impact of elevated temperature during two critical stages of reproductive development: inflorescence initiation in season 1 and inflorescence development during budburst in season 2.

Light and fluorescent microscopy on grape buds of a key commercial variety has revealed the morphological and anatomical features of compound buds in tropical Broome and Mediterranean Swan Valley. Contemporary microscopy and histology approaches are currently evaluating the comparative development of the inflorescence primordia (IP) between these two climates. Data from fruit size and yields in the different climates suggests the IP are not developing sufficiently or optimally within the latent/compound buds during the growing season.

Building upon these field observations, our research further investigates the physiological mechanisms underlying temperature effects on reproductive development during season 2. We focus particularly on ascorbate-glutathione pathways, which are key antioxidants for reduction/oxidation homeostasis and metabolic control.

This research will provide valuable insights into the temperature-dependent regulation of grapevine reproductive development and the underlying metabolic mechanisms involved. The findings will establish foundation knowledge to boost yields and enable viticulture expansion in northern Australia, while also addressing future warmer climate scenarios in southern Australia.

This research is supported by UWA - CRC Innovating the Growth of Tropical Table Grapes.

Antioxidants as master regulators of growth and stress resilience in grapevine

Project team: Associate Professor Michael Considine[1] (Project leader; michael.considine@uwa.edu.au), Professor Christine Foyer[3], Dr Paul Boss[2], Christine Bottcher[2], Dr Aneta Ivanova[1], Wenyi Xu[1], Shivanagouda Haranal[1].

Collaborating organisations: [1]UWA; [2]CSIRO; [3]University of Birmingham, UK.

Antioxidants are important for plant growth and development. Deficiencies in ascorbate (vitamin C) or glutathione - the two most important soluble antioxidants in plants - results in slow and stunted growth and susceptibility to environmental stress. This is because, in addition to protecting molecules from oxidation, they are critical to recycling of metabolic intermediates and control hormone synthesis. This knowledge has been incredibly valuable for crop improvement in cereals and legumes but has yet to be applied to woody perennials, such as grapevine.

Grapevine is an incredibly important crop for fresh and processed fruit industries and has become a model for understanding how perennial tree crops adapt to climate and changes in seasonality.

A research team led by UWA, in collaboration with CSIRO in Adelaide, developed genetically modified grapevine lines deficient in either ascorbate or glutathione.

Characterisation of these genotypes began in 2024, focusing on growth and stress responses. As shown, the ascorbate-deficient lines exhibit slow growth, whereas glutathione-deficient lines display growth patterns comparable to the parent line. The availability of multiple genetically distinct lines deficient in each antioxidant enables a detailed investigation into the roles of these compounds in grapevine growth and in responses to elevated temperatures.

These findings represent an initial step toward enhancing the resilience of grapevine and other perennial fruit crops to climate-related stress, pests, and diseases.

This research is supported by ARC Discovery (DP210102178).

Potted genotypes of grapevine that are genetically deficient in ascorbate (foreground) by comparison with the unmodified parent line (background), showing severe growth phenotypes.

Associate Professor Michael Considine showcasing the modified and unmodified grapevine lines in the PC2 glasshouse.

Integrating phenomics into genomic prediction of target traits for apple breeding (ICHDR1)

ANABP accessions at flowering stage at the selection block of Manjimup Horticultural Research Institute, DPIRD.

Seedlings of a crossed progeny at the nursery of Manjimup Horticultural Research Institute, DPIRD.

Project team: Dr Sultan Mia[1] (Project leader; sultan.mia@dpird.wa.gov.au), Associate Professor Michael Considine[2]

Collaborating organisations: [1]DPIRD; [2]UWA.

Traditionally, apple breeding has been a time-consuming and resource-intensive process, spanning several decades from initial cross-pollination to commercial availability. However, with advancements in high-throughput genomics, phenomics, and data analytics, a paradigm shift is occurring globally.

Modern breeding has now evolved into a highly advanced, multi-disciplinary science that is data-driven and predictive in nature. The Australian National Apple Breeding Program (ANABP) is a leader in developing and releasing commercially successful apple varieties. Within ANABP, there are significant opportunities for advancing and applying marker-assisted selection strategies, enhancing genomic selection models for a range of traits, and improving the accuracy of predictions to support informed selection decisions for future environments.

This project will aim at exploring the genomic variation of the ANABP accessions and developing a more streamlined phenotyping platform for traits of interest including flowering and self-incompatibility for improved genotype-phenotype matching.

Have partnered on a five-year initiative as part of the ARC-funded project "IC230100016 ARC Training Centre for Predictive Breeding for Agricultural Futures (ARC PBAF)", led by the University of Queensland. DPIRD is contributing both cash and in-kind support, while UWA is hosting a PhD student who will undertake research aligned with a priority project of ANABP.

This collaboration aims to advance predictive breeding approaches and contribute to the development of improved apple varieties tailored to future agricultural challenges.

This research is supported by UWA, Australian Research Council, University of Queensland and DPIRD.

Novel agronomic practices to achieve productive and profitable viticulture in northern Australia: Part 1 – IPM

A grapevine decimated by *S. litura* (tobacco cutworm) in Broome.

Aimee Grieves (DPIRD, Broome) examining a grapevine leaf showing extend of damage caused by *S. litura* (tobacco cutworm).

Project team: Associate Professor Michael Considine[1] (Project leader; michael.considine@uwa.edu.au), Professor John A. Considine[1], Dr Julia Grassl[1,2], Dr Chris Ham[2], Dr Kiran Mahat[2], Aimee Grieves[2].

Collaborating organisations: [1]UWA; [2]DPIRD.

Pest and disease pressure is a common challenge in low-latitude cropping systems, necessitating significant investment in the development of sustainable agricultural practices. Cotton, for example, is well-documented for its vulnerability to damage from migratory, polyphagous moth larvae, particularly species of Spodoptera and Helicoverpa.

An initial focus on investigating the physiological and agronomic adaptation of Vitis vinifera to tropical and subtropical environments shifted when substantial pest and disease threats were identified at the Roebuck Plains site, located east of Broome.

The primary pest observed was *Spodoptera litura* (tobacco cutworm), a species endemic to the Indo-Australian and Pacific tropics and subtropics. Although typically found in isolated regions of the northwest, its presence in this emerging viticulture zone posed a significant threat. In response, an intensive pesticide spray program was implemented by site managers. However, this approach was soon deemed unsustainable due to the pest's capacity for rapid resistance development. *S. litura* is particularly prolific, with individual females capable of laying up to 7,500 eggs during a 12-day lifespan. The resulting larval infestations can cause severe defoliation.

To address this challenge, a monitoring program was established involving pest trapping and mapping to evaluate pest incidence, climatic influence, and potential migratory patterns. In parallel, a collaborative initiative with DPIRD WA, and its counterpart in New South Wales (DPIRD NSW), was launched to investigate the pesticide resistance profiles of local *S. litura* populations. DPIRD WA intends to expand the use of this resistance-mapping technology across northern WA.

A significant development has been the establishment of a partnership with Shin-Etsu Chemical Co. (Japan), a company specialising in the synthesis of pheromones for insect traps and mating disruption—an integrated pest management (IPM) technique. With authorisation from the Australian Pesticides and Veterinary Medicines Authority (APVMA), a limited quantity of donated pheromone lures was imported and trialled in the local environment. Despite initial expectations of limited effectiveness due to the typically regional scale of such interventions, the results were both immediate and promising, indicating the potential for sustainable, site-specific deployment.

Encouraged by these results, efforts are underway to import additional donated lures for a 20-hectare commercial evaluation. An APVMA registration application is being prepared. Furthermore, the technology will be trialled beyond grapevines, including on an asparagus farm.

Further updates will include findings on local biological control agents, including predators and entomopathogens affecting *S. litura* populations.

This research is supported by CRC-Developing Northern Australia, Fresh Produce Group (Fruitico) and DPIRD.

Novel agronomic practices to achieve productive and profitable viticulture in northern Australia: Part 2 – Agronomy/Physiology

Project team: Associate Professor Michael Considine[1] (Project leader; michael.considine@uwa.edu.au), Professor John A. Considine[1], Dr Julia Grassl[1,2], Dr Chris Ham[2], Aimee Grieves[2], Pragya Poudel[1], Noor Shaik[1], Wenyi Xu[1].

Collaborating organisations: [1]UWA; [2]DPIRD.

The goal of this project is to facilitate the development of high-value horticultural crops in northern Australia. Horticultural cropping in Carnarvon, for instance, is valued at approximately $70,000 per hectare, compared to around $5,000 per hectare in the Ord River Scheme. Low-latitude regions also provide opportunities for 'out-of-season' production, which can support import replacement and lead to higher unit values.

The cultivated grapevine is deciduous and displays bud dormancy, a topic that has long been of interest to the team. It is photoperiod and temperature sensitive, signals that are absent in low latitude regions.

Water-deficit stress has been used traditionally to substitute for these signals enabling two or more crops per year (e.g. India and Venezuela – reported by Baron von Humbolt 1790's). However, each region has its own attributes and needs customising. There are also penalties in production that need to be resolved often being as little as 10% of that in a more appropriate climate. Our challenge is to identify the sources of limits to yield and to offer a path to improved yield through novel agronomic interventions.

Previous research found the state of dormancy to be low and erratic in grapevines growing in Carnarvon. In Broome, dormancy appears absent, and without management, vines may exhibit continuous growth, including erratic activation of latent, fruit-bearing buds. The primary limitation to productivity, however, appears to lie not in dormancy itself, but in impaired reproductive development and disruptions in carbon allocation.

The biomass of grapevines growing in the Kimberley is about one-third of that of those growing in Carnarvon or more southerly regions such as the Swan Valley. While grapevines have been shown to adapt well to temperature as high as 35°C, temperature above 40°C can lead to leaf death. So assimilation is probably down but respiration up, probably in a non-linear fashion. This may be the principal factor limiting productivity, though the lower root mass induced by high soil temperature probably contributes. There is more work to be done in this area. We are investigating field hydro-cooling as an option to offset these factors.

More obvious to the grower is the poor development of inflorescences. While there is limited published information on the impact of extreme temperature and radiation, it appears that temperature greater than about 32°C has a negative impact on induction and development. High temperature during bud burst has an additional negative impact limiting inflorescence primordium proliferation. These aspects are poorly understood and are the subject of a PhD study. Again, hydro-cooling may ameliorate these developmental limitations.

Beyond the relationship between assimilation and respiration, other aspects of the carbon economy may influence productivity. In grapevines, sugar loading into the phloem is predominantly passive; active transport occurs during berry ripening (post-veraison) and potentially during the remobilisation of carbohydrate reserves from starch stored in xylem parenchyma.

In collaboration with Professor Leigh Schmidtke (Charles Sturt University), attenuated total reflectance Fourier transform infrared (ATR-FT-IR) spectroscopy is being adapted to enable rapid assessment of starch concentrations in grapevine tissues. This tool may facilitate informed pruning decisions regarding both timing and severity. Insufficient starch reserves at key developmental stages may result in the inflorescence being outcompeted by the shoot apex for assimilates, often leading to inflorescence abortion and complete yield loss. Current investigations are focused on optimising carbon partitioning during this critical phase of development.

Top image: Ms Aimee Grieves measuring berry size at harvest in Broome, showing that production of high quality fruit is possible.

Bottom image: Research Assistant Ms Wenyi Xu and PhD students Mrs Pragya Poudel and Mr Noor Shaik (left to right) examining buds from a temperature experiment in a growth cabinet at UWA, Crawley.

This research seeks to systematically identify climatic and physiological constraints on grapevine productivity in tropical regions, while concurrently evaluating agronomic practices aimed at mitigating those constraints and enhancing crop development and yield.

This research is supported by CRC-Developing Northern Australia, Fresh Produce Group (Fruitico) and DPIRD.

Associate Professor Michael Considine and Dr Simon Whittock assessing the harvest quality of select varieties and breeding lines from the HPA farm in Victoria.

Advanced breeding techniques for high quality hop varieties

Project team: Associate Professor Michael Considine[1] (Project leader; michael.considine@uwa.edu.au), Associate Professor Gavin Flematti[1], Dr Simon Whittock[2].

Collaborating organisations: [1]UWA;[2]HPA.

The distinct qualities of hops are a major defining feature of the global craft beer industry. Hop Products Australia (HPA), has bred a number of world-leading hop varieties, including Galaxy®, Ella®, Enigma® and Eclipse®.

Galaxy is recognised as one of the top 10 varieties globally. However, Galaxy is susceptible to postharvest oxidation, which diminishes quality and flavour. Remarkably, several siblings of Galaxy do not share this problem. To date, the biochemical and genetic basis of this susceptibility is not known.

In 2024, UWA, was part of a national team awarded a federal training centre by the Australian Research Council, to develop the next generation of crop and livestock breeders. HPA joined the team as an industry partner to sponsor a PhD student.

Although the PhD scholarship has yet to be awarded, this project will advance not only Australia's breeding talent but contribute to strategic improvements in the HPA breeding program, giving Australia a strong competitive edge over international breeding programs.

This research is supported by ARC Industrial Transformation Training Centre in Predictive Breeding for Agricultural Futures and Hop Products Australia Ltd.

Associate Professor Michael Considine inspecting hops on the bine at HPA, Victoria.

Molecular marker-based parent selection from Australian National Apple Breeding Program (ANABP) germplasm targeting fruit quality traits

Project team: Dr Sultan Mia[1] (Project leader; sultan.mia@dpird.wa.gov.au), Associate Professor Michael Considine[2], Md Mosiur Rahman Bhuyin Apu[2].

Collaborating organisations: [1]DPIRD [2]UWA.

Developing superior apple cultivars with desirable fruit quality traits is essential for meeting market demands and consumer preferences. Traditional apple breeding generally relies on phenotypic selection methods, which are time-consuming and influenced by environmental factors.

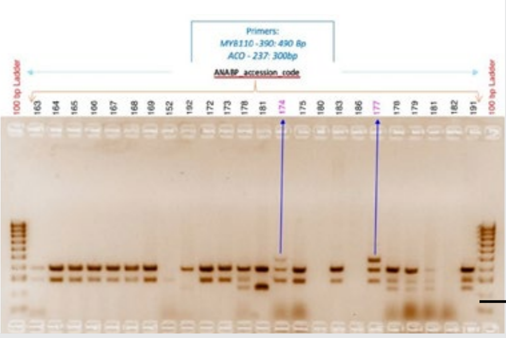
Implementation of molecular marker-assisted selection (MAS) into the breeding process enhance efficiency and precision. By utilizing molecular markers linked to essential fruit quality attributes, breeders may make educated decisions during designing crossing scheme and then the seedling selection stage, hence saving critical resources. This study underscores the value of MAS in identifying promising parent genotypes, with advantageous allele combinations for the fruit quality related traits allowing breeders to make early, informed decisions.

In this study, 192 apple germplasm accessions were analysed using nine genetic markers associated with fruit quality traits, including skin and flesh colour, texture, acidity, and susceptibility to bitter pit. Results indicated a high prevalence of the 390 bp allele in the MYB10 marker, which is linked to white flesh colour, while a smaller proportion of accessions carried the 490 bp allele associated with red flesh.

Analysis of the RED TE marker revealed that the majority of accessions possessed the allele associated with red skin colour. Markers related to texture (ACS, ACO, and Md-PG1) exhibited significant allelic diversity, influencing firmness and juiciness. The Ma Indel marker showed variation associated with fruit acidity, while the BP16 and BP13 markers offered insights into bitter pit susceptibility.

These findings highlight the utility of MAS in identifying parent genotypes with favourable allele combinations for fruit quality traits. The approach facilitates early, informed decision-making in apple breeding programs and provides valuable genetic insights that can be leveraged by initiatives such as the Australian National Apple Breeding Program (ANABP) to enhance breeding strategies.

This research is supported by UWA and DPIRD.



Sample collection, DNA extraction and genotyping process.

Tractor Fertilising Agricultural Field at Sunset.

5

Engineering for Agriculture

The Engineering for Agriculture 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 per cent 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, enabling us to respond efficiently to new challenges and opportunities as they arise. This theme also presents extensive opportunities for collaboration between farmers, agricultural machinery manufacturers and the IOA, to undertake research and development focused on bringing about commercial innovation.

Theme Leaders

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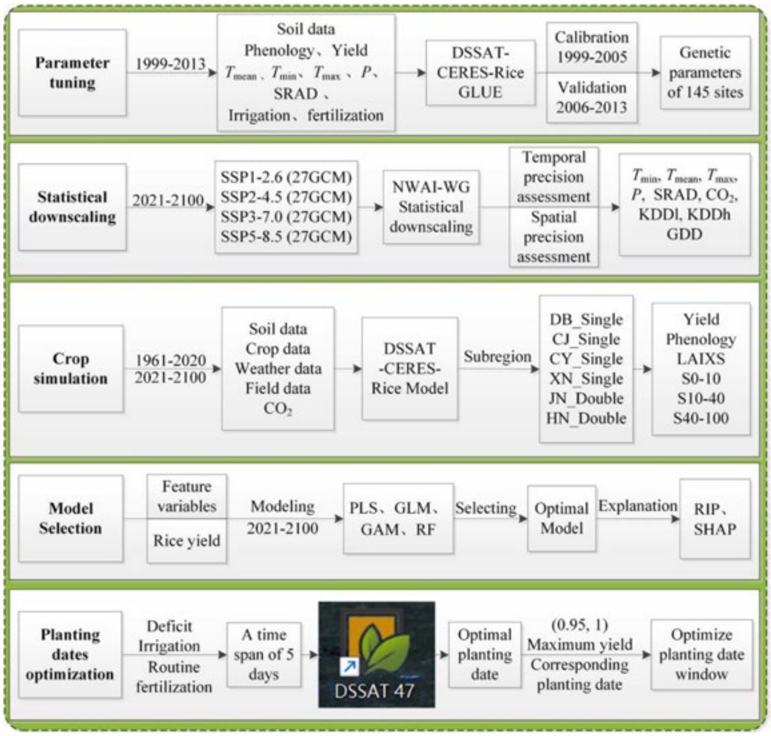
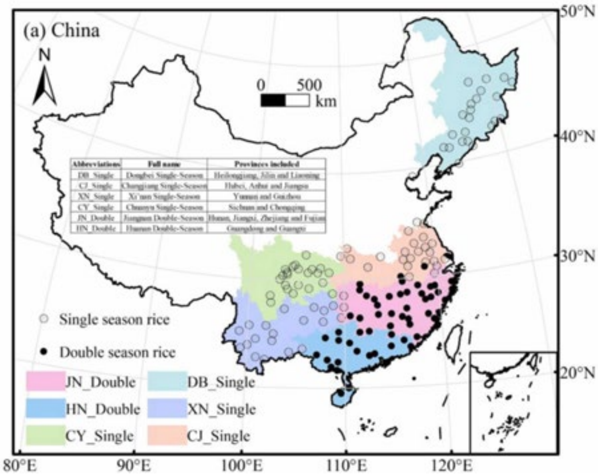
Game analysis of future rice yield changes in China based on explainable machine-learning and planting date optimization





Above image: Division of rice planting areas and spatial distribution of 91 agrometeorological stations for single cropping rice and 54 agrometeorological stations for double cropping rice in China.

Left image: Research framework including data collection and methods.

Project team: Professor Yi Li[2,3] (Project leader; liyi@nwafu.edu.cn), Hackett Professor Kadambot H.M. Siddique[1], Ziya Zhang[2,3,4], Lulu Xie[4], Shiqiong Li[5], Hao Feng[4], Guozhen Lin[6].

Collaborating organisations: [1]UWA; [2]Yellow River Engineering Consulting Co.; [3]Ministry of Water Resources, China; [4]Northwest A&F University, China; [5]Wuhan University, China; [6]Yunnan Survey and Design Institute of Water Conservancy and Hydropower, China.

This study explores the impacts of climate change on rice yield in China, specifically investigating how varying temperatures, precipitation, and planting dates interact with rice phenology. The research integrates crop models with machine learning techniques, notably the Random Forest (RF) model, to predict rice yield and understand regional disparities.

Projections show that rising CO_2 levels may slightly improve yields for single-season and early rice by 0.1-9.5%, while late rice yields still face declines of 2.3-8.8%. The combination of RF with crop models such as DSSAT was found to be the most accurate in predicting rice yield, enhancing the model's ability to capture complex environmental interactions.

The study also reveals that temperature, particularly Growing Degree Days, has a more negative impact on yields than other factors. In high-precipitation regions, deep soil moisture plays a more significant role than shallow moisture, while the opposite is true in drier regions. Furthermore, adjusting planting dates was shown to boost yields for early and single rice crops by 3.3-18.3%, but late rice crops still experienced reduced yields. The research suggests that modifying planting schedules could be an effective, cost-efficient strategy to mitigate climate change impacts on rice yields.

The incorporation of machine learning and statistical methods into crop models, with the added transparency of SHAP for interpretability, offers an innovative approach to yield prediction. These hybrid models help researchers understand the interplay of various environmental variables, providing valuable insights for future agricultural strategies.

This study underscores the importance of optimising planting dates and utilising advanced modelling techniques to ensure food security under climate change.

This research is supported by the Research Fund of Key Laboratory of Water Management and Water Security for Yellow River Basin, Ministry of Water Resources and NNSFC.

Centre for Engineering Innovation: Agriculture & Ecological Restoration

Project team: Associate Professor Andrew Guzzomi[1] (Project leader; andrew.guzzomi@uwa.edu.au), Professor Michael Walsh[1,2], Dr Todd Erickson[1], Trent Mahony[1], Dr Carlo Peressini[1], Dr Monte Masarei[1], Dr Wesley Moss[1], Dr Luke Omoarelojie[1], Dr Stuart Watt[1], Lee Hunt[1], Yvonne Zago[1], William Richards[1], Stephanie Lye[1], Eve McCallum[1], Ruby Wiese[1], Dr Harrison Caddy[1], Yuval Juran[1].

Collaborating organisations: [1]UWA; [2]Charles Sturt University.

The Centre for Engineering Innovation: Agriculture & Ecological Restoration (CEI:AgER) at UWA Shenton Park Field Station continues to build upon its strong relationships with innovative farmers and industry groups and sustained track record of solving interdisciplinary challenges facing the agricultural and environmental sectors.

The Centre's mission is to provide engineering solutions and methodologies for agricultural prosperity and ecological restoration. With practicality, commercialisation, and easy adoption in mind, the team aims to enhance the social value, economic value, and sustainability of agricultural and environmental resources.

In 2024 CEI:AgER highlights included:

- Hosted visitors from Federal University of Viçosa Brazil, Kimberley Rangers and Planfarm.
- Dr Wesley Moss, Dr Monte Masarei and A/Professor Andrew Guzzomi travelled to Italy for EIMA Conference, meetings with CNH R&D and the University of Bologna
- Dr Wesley Moss awarded a tenured track role.
- Shenton Park Field Station had its second biennial Open Day.
- State of the art CNC machine installed in the workshop.
- Provisionally patented 2 active weeding tool devices.
- 6 MECH5552 Capstone Mechanical Design projects with SwarmFarm, Waringa, Primary Sales, Australian Wildlife Conservancy, Global Neighbor for the AgMachinery/AgTech/EcoTech industries.
- Novel weed experiments on water jet cutting.
- Presented a stall at evokeAg 2024.
- Presented at a number of conferences.
- Establishment of spinout company based on CEI:AgER's ecological restoration technology stack and service offering

This research is supported by UWA.

The CEI:AgER team presenting at the Shenton Park Field Station Open Day.

Caleb McKenna (prior masters student), Dr Monte Masarei, A/Prof Andrew Guzzomi and Dr Wesley Moss at the EIMA conference in Italy.

Mechanical in-crop weed control

Project team: Associate Professor Andrew Guzzomi[1] (Project leader; andrew.guzzomi@uwa.edu.au), Professor Michael Walsh[1,2], Dr Carlo Peressini[1], Dr Stuart Watt[1].

Collaborating organisations: [1]UWA; [2]Charles Sturt University.

Herbicide resistance is estimated to cost farmers $108 million annually and threatens crop yields, ultimately threatening Australia's food security. There are currently no alternatives to herbicides for weed control in large-scale crop farming.

This project seeks to develop a mechanical system for in-crop weed control as a non-chemical alternative in large-scale row-crop farming. Combining expertise in engineering and weed science, the team is collaborating with leading farmers, innovators, industry partners, and machinery manufacturers across WA, NSW, and QLD to create practical, scalable solutions.

This work builds on the work of the initial Weed Chipper project which was developed as a targeted tillage system for fallow weed control and was funded by the GRDC.

Highlights for 2024 include:

- Development continued on the targeted tillage implementation at the UWA Shenton Park Field station over the first half of 2024. During this period, the mechanical tool was refined along with the motor control strategy.
- In the second half of the year, two prototype rigs were developed for interstate testing. A single-tyne rig was built and sent to Wagga Wagga, NSW, for weed efficacy trials. A 7-tyne rig was developed with standalone power system, to be shipped to a farm near Toowoomba, Queensland, for testing in-crop.
- In October, the team travelled to Wagga Wagga to facilitate the weed kill efficacy trials. The results were extremely successful, with the implement showing very high kill rates (near 100%) on all weeds hit.

This research is supported by UWA and DAFF.

Engineering 3-tyne test rig at Shenton Park Field Station.

Weed-kill efficacy trials at Wagga Wagga using a single-tyne rig.

Project team working on machinery in the field.

Andrew Guzzomi holding a swathed row of sub clover material.

Building new tech for sustainable sub clover seed harvesting

Project team: Associate Professor Andrew Guzzomi[1] (Project leader; andrew.guzzomi@uwa.edu.au), Professor Megan Ryan[1], Associate Professor Phillip Nichols[1], Dr Wesley Moss[1], Ruby Wiese[1], Joe Shaw[1], Bradley Wintle[1], Dr Ann Hamblin[1], Lee Hunt[1], Minie Meng[1], Adrian Tsoi[1], Yvonne Zago[1].

Collaborating organisations: [1]UWA.

Australia is the world's largest producer and exporter of sub clover seed, but its global supply is threatened by challenges facing the seed production industry. The industry is currently reliant on suction harvest technology that is slow and takes a heavy toll on the soil.

This project aimed to build and test new technologies that can be adopted for the sustainable and profitable harvesting of sub clover seed. To introduce new technology that can address some of these issues, the research is investigating a swathing approach that harvests sub clover seed without suction and causes significantly less soil disturbance.

This follow-on AgriFutures project builds upon the extensive knowledge base and relationships developed through the predecessor 'Profitable and Environmentally Sustainable Sub Clover and Medic Seed Harvesting' project.

The research team, comprising skills in agricultural engineering, pasture agronomy and plant physiology, is working with a range of leading seed growers and pasture seed companies in WA, SA, NSW and Vic to address seed production issues. Subterranean clover (or sub clover) is Australia's most widely grown annual pasture legume and is considered the backbone of Australia's sheep and beef pastures.

The multidisciplinary project team is conducting research across engineering, agronomy and economics to understand how new approaches will affect the plant's biology and the impacts on the seed production industry.

The Agrifutures funded project concluded in 2024, but the research team is continuing to develop technology and techniques to benefit the seed production industry.

This research is supported by UWA and AgriFutures Australia.

Evaluation of the agronomic performance of novel methods for sustainable subterranean clover (Trifolium subterraneum L.) seed harvesting

Project team: Ruby Wiese[1] (Project leader; ruby.wiese@research.uwa.edu.au), Associate Professor Andrew Guzzomi[1], Professor Megan Ryan[1], Dr Wesley Moss[1], Associate Professor Phillip Nichols[1].

Collaborating organisations: [1]UWA.

Subterranean clover (Trifolium subterraneum L.) is an invaluable annual pasture legume for Australian agriculture with the unique trait of burying its seeds below-ground. While desirable for pasture persistence, this trait makes harvesting the seed difficult.

Current seed harvesting practice revolves around the Horwood Bagshaw Clover Harvester and although effective, the process is inefficient, can degrade soil and cause erosion, and relies on ageing, outdated harvesters. Swathing is an alternative harvesting method which addresses these issues.

Before plants have fully senesced, plant roots are cut, plants lifted and windrowed so that dried plants can be harvested with a combine. The study of Ruby Wiese's PhD aims to investigate the feasibility of a swathing approach for harvesting subterranean clover.

A key consideration of effective swathing is timing: swathing too late when plants are dry and brittle results in poor seed retention yet swathing too early may result in decreased yield and collection of immature seeds with poor quality. Hence, Ms Wiese has investigated changes over time during seed maturation of seed yield and quality, as well as seed retention during swathing.

This PhD project is part of a larger AgriFutures Australia-funded project (see page 100) investigating novel methods for harvesting subterranean clover seed which address the shortfalls associated with the current Horwood Bagshaw process. Development of a more efficient harvesting method will make this pasture legume more accessible globally.

As sub clover offers nitrogen fixation, high nutritive value, and strong persistence due to hardseededness and high tolerance of heavy grazing, more widespread establishment and frequent renovation of sub clover-based pastures represents a significant benefit to livestock and cropping systems around the world.

In 2024, Ms Wiese was awarded a Mike Carrol Travelling Fellowship award which allowed her to attend the International Plant Phenotyping Symposium held in Lincoln, Nebraska in the USA. This was an opportunity for Ms Wiese to meet international collaborators in the plant phenotyping space and find inspiration for future PhD experiments in this research area.

This research is supported by UWA, AgriFutures Australia, the Australian Government Research Training Program Stipend, and an AW Howard Memorial Trust Research Fellowship.

PhD student Ruby Wiese discusses her research with the PlanFarm team during their visit to CEI:AgER.

Ruby Wiese images potted subterranean clover plants at a range of developmental stages at the UWA Plant Growth Facility.

Melaleuca Bark Board

Project team: William Richards[1] (Project leader; william.richards@research.uwa.edu.au), Associate Professor Andrew Guzzomi[1], Dr Monte Masarei[1], Professor Xiao Hu[1].

Collaborating organisations: [1]UWA; [2]Australian Government Department of Education.

A new sustainable engineered wood product is being developed from Melaleuca bark. Paperbark trees are currently not widely used for commercial purposes. However, with restrictions on logging state forests being introduced across Australia and increasing construction material costs there is potential for a new product to be developed.

By harvesting the bark of established trees (similarly to the cork industry of Portugal) a material can be produced without felling trees. Various Melaleuca species additionally grow on land not suitable for conventional agriculture such as swampy and saline conditions. This project aims to develop a novel material utilising Melaleuca bark.

The current focus of the project has been on utilising temperature and pressure to bind the boards without the need for synthetic adhesives or resins that are often used in plywood and particleboard.

Current results indicate that the material may be suitable for use in cabinetry, achieving similar strength and water absorption to low strength plywood. An article titled "Adhesive free Melaleuca rhaphiophylla (Swamp Paperbark) bark as an engineered wood product" was published in European Journal of Wood and Wood Products.

This research is supported by the Department of Education, Australian Government.

Restored landscape.

Restoration Engineering Seed Technology Deployment Program and Australian Seed Scaling Initiative

Project team: Dr Todd Erickson[1] (Project leader; todd.erickson@uwa.edu.au), Associate Professor Andrew Guzzomi[1], Dr Monte Masarei[1], Dr David Merritt[1,5], Dr Luke Omoarelojie[1], Dr Harrison Caddy[1], Eve McCallum[1], Stephanie Lye[1].

Collaborating organisations: [1]UWA; [2]BHP; [3]Alcoa; [4]Botanic Gardens and Parks Authority; [5]Department of Biodiversity, Conservation and Attractions.

Accurately and efficiently using wild collected native seeds to initiate plant establishment is a critical challenge to large scale ecological restoration and rehabilitation. As climate change reduces the availability of viable seed stock, current failings and inefficiencies in native seed handling and planting will impact restoration outcomes more severely.

Therefore, increasing the efficiency of seed performance in ecosystem rehabilitation for mined and agricultural landscapes is paramount to ensure positive restoration outcomes.

CEI:AgER is working in two projects work to develop technology and systems to process, enhance and more efficiently precision sow diverse mixes of wild-collected seeds.

The work extends across the spectrum of seed enhancement techniques (e.g. the CEI:AgER developed Seed Flamer) to new methods to effectively sow seed.

These mechanised sowing methods have been deployed and tested across a variety of challenging to seed landscapes, ranging from sites in the complex ecosystems of the South West, to the rugged terrain of the Pilbara. The engineers and scientists at CEI:AgER in the project team collaborate extensively with seed scientists at Kings Park Science.

This research is supported by UWA, BHP and CRC TiME.

Grain Automate - Developing capability, awareness, and preparedness for autonomy in the tertiary education sector

Project team: Associate Professor Andrew Guzzomi[1] (Project leader; andrew.guzzomi@uwa.edu.au), Dr Wesley Moss[1] (Project leader; wesley.moss@uwa.edu.au), Dr Stuart Watt[1], Alysia Kepert[1], Emeritus Professor Graeme Martin[1], Dr Gustavo Alckmin[1], Professor Marit Kragt, Associate Professor James Fogarty[1], Karen Eyles[1].

Collaborating organisations: [1]UWA; [2]Australian Government Department of Education.

The Grains sector is changing radically, with technology affecting every aspect: producers, logistics, manufacturing, marketing, and export. In response, GRDC has launched Grain Automate, an innovative, five-year initiative to accelerate the adoption of machine automation, autonomy, and digital intelligence technologies by Australian grain growers.

Meeting this objective requires a sustainable talent pool with the capability, awareness, and preparedness to adopt and leverage advancing technology.

To address this, CEI:AgER is delivering as part of Grain Automate Program 1: 1 Developing capability, awareness, and preparedness for autonomy in the tertiary education sector.

This requires supporting education and training on two fronts:

- prepare the workforce on the emerging technologies;
- address the massive shortage of new professionals.

In this context, CEI:AgER is developing micro-credentials to meet these needs: i) educational material to upskill tertiary students and workforce; and ii) 'train the trainers', to upgrade secondary teachers so they can teach new agriculture curricula and prepare and excite students about the future of agriculture.

Alongside other initiatives (e.g. student events) this will support growers and industry in building the needed knowledge, understanding and capabilities to implement more advanced and profitable applications of machine and implement automation; while also expanding the pipeline of students entering agriculture and ensuring the talent pool exists to support the future of the Grains industry.

Team conducting tech scouting at EIMA Agricultural Machinery Conference in Bologna.

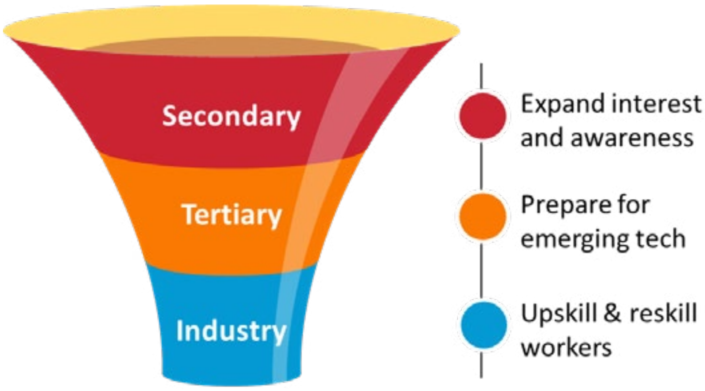


Diagram of proposed activities, with the intention to grow the funnel of learners moving from secondary, tertiary and eventually into skilled industry professionals ready to leverage emerging technology.

The key project outcomes will be micro-credential resources applicable across students, educators and workforce (current and future), that scaffold the learning journey based on grower/learner circumstances or aspirations. These will be deployed through UWA's established "UWA Plus" micro-credential framework.

The project launched in 2024 and has begun by working with partners across education and industry, both domestically and abroad, to understand the current landscape and develop outlooks for the future of technology to inform new educational material. This included tech scouting in Italy that encompassed a visit to EIMA Agricultural Machinery conference in Bologna and meetings with Case New Holland.

Agricultural Technology Microcredentials will be piloted in 2025 with places funded by the Australian Federal Government "Microcredentials Pilot in Higher Education" scheme.

This research is supported by GRDC.

Locally grown vegetables on display at a farmer's market.

6

Agribusiness Ecosystems

The agribusiness ecosystem refers to the network of interconnections and linkages among agricultural enterprises and between these and non-agricultural businesses involved in the exchange of goods and services. At its core, the ecosystem is driven by the creation of economic value - the central focus of all commercial activity.

Borrowed from biology, the term "ecosystem" describes the dynamic interaction between living organisms and the non-living elements of their environment—such as water, soil, minerals, and air. These interactions form the basis of a functioning and resilient ecosystem. Similarly, the strength and resilience of an agribusiness ecosystem depend on the quality and intensity of relationships and interdependencies among its constituent parts.

Agribusiness includes a wide range of enterprises and activities across the entire agricultural value chain—from the supply of farm inputs and on-farm production to manufacturing, processing, distribution, wholesaling, and retailing of agricultural products to the final consumer. These enterprises are deeply interconnected, and the success of any one firm is not determined solely by its internal operations. Instead, it depends on its ability to leverage the complementary capabilities, resources, and knowledge available within a broader network of firms and institutions. These include not only other agricultural enterprises but also non-agricultural entities such as banks, insurance companies, government bodies, and educational institutions.

At The UWA Institute of Agriculture, the Agribusiness Ecosystems theme is dedicated to advancing scholarship on the socio-economic dimensions of agriculture. This includes research at the local level in Western Australia, nationally across Australia, and globally in both developed and developing countries. A multidisciplinary team of scholars and professional experts within this theme addresses issues related to the governance, productivity, profitability, and sustainability of agribusiness enterprises and industries. Their work provides innovative policy solutions through research, education, training, and capacity building.

This report presents key highlights of the research and training activities undertaken through the Agribusiness Ecosystems theme in 2024. Our efforts contribute to the advancement of the United Nations 2030 Agenda for Sustainable Development.

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UWA members of the BITA Training Centre. (L-R): German Puga, Mithun Ghosh, Mahnaz Afsar, Prof Marti Kragt, A/Prof Fay Rola-Rubzen, Yadav Padhyoti.

ARC Industrial Transformation and Training Centre for Behavioural Insights for Technology Adoption (BITA)

Project team: Professor Marit Kragt[1] (Project leader; marit.kragt@uwa.edu.au), Associate Professor Ben White[1], Associate Professor Steven Schilizzi[1], Associate Professor Fiona Dempster[1], Associate Professor Fay Rola-Rubzen[1], Associate Professor Amin Mugera[1], Associate Professor Andrew Guzzomi[1], Dr German Puga[1], Ms Tamara Harold[1], Ms Mahnaz Afsar[1], Mr Yadav Padhyoti[1], Mr Mithun Kumar Ghosh[1].

Collaborating organisations: [1]UWA; Queensland University of Technology; The University of Queensland; Clear Grain Exchange; Grower Group Alliance; Agora Livestock; Smart Paddock.

Australia needs accelerated adoption of innovation technologies to improve outcomes in health, agriculture and cybersecurity. Despite technically viable solutions, innovations fail to be adopted due to behavioural barriers. Behavioural approaches can promote significant gains by bridging the barriers to technology adoption.

The ARC Training Centre for Behavioural Insights for Technology Adoption (BITA) was launched in 2023 to better understand and overcome the behavioural barriers that impede the widespread adoption and diffusion of innovative technologies. In collaboration with industry and government partners, BITA will boost productivity and adoption of innovation, support businesses to grow with people-focused innovation, and enable more innovative new products and services to reach end-users in local, domestic and global markets.

The interdisciplinary team of behavioural economists, psychologists and social marketers are working together and with industry to address the challengers and try to improve outcomes in health, agriculture, and cyber-security.

During 2024, the UWA team was finalised with the appointment of the postdoctoral research fellow, Dr German Puga, and three PhD research students, Ms Mahnaz Afsar, Mr Yadav Padhyoti and Mr Mithun Kumar Ghosh. Research proposals are underway and have been presented at UWA and at the recent BITA Research Showcase event in Brisbane, October 2024.

The next steps are to work with industry partners, such as Growers Group Alliance (GGA), to gather data and guide the research to ensure practical and impactful outcomes for the agricultural industry.

This research is supported by UWA and BITA.

UWA BITA member, Dr German Puga, presents a research proposal at the ARC BITA Research Showcase (Brisbane, October 2024).

A property just outside of Perth.

Barriers and opportunities for agricultural natural capital as an asset class

Project team: Associate Professor Ram Pandit[1] (Project leader; ram.pandit@wabsi.org.au), Mr Thomas Picton-Warlow[2], Dr Jon Sarmiento[1], Dr Fiona Dempster[1], Dr Lizzy Lowe[3], Mr Oral McGuire[4].

Collaborating organisations: [1]UWA; [2]MobileGlobal; [3]Edith Cowan University; [4]Yaraguia; Mingenew Irwin Group; Southern Forests Food Council; Southern Rangelands Pastoral Alliance; Stirlings to Coast; ASHEEP + BEEF; Wheatbelt NRM; South Coast NRM; South-West NRM; Facey Group.

This project aims to prepare Western Australia for the paradigm shift in natural resource management in agricultural systems by understanding the potential of "Natural Capital" production landscapes as an asset class.

The UWA research team are engaging with key stakeholders, including grower groups, farmers, investors and natural resource management (NRM) groups, to establish a baseline understanding of attitudes towards productive natural capital and nature as an asset. This will include the identification of knowledge gaps, perceptions of risk, perceptions towards nature repair, and probability of integrating natural capital into their farming businesses and collaboration as a group.

During 2024 the team conducted over 30 interviews with investors and held 8 regionally located educational workshops and online presentations for the farmers, grower groups and NRMs on natural capital production landscapes. The workshop delved into the potential of a Natural Asset Company equity structure to drive significant changes in Western Australia.

Insights are currently being analysed. Findings from the project will help policymakers understand the expectations among stakeholders, which will inform the definition of more effective, user-focused strategies.

This research is supported by UWA and SW WA Hub, through funding from the Australian Government's Future Drought Fund.

Thomas Picton-Warlow - 11th September 2024 presenting to pastoralists at Gascogne Junction for Southern Rangelands Pastoralists Association.

Looking Back – Looking Forward: the economic and social contributions of the Western Australian co-operative and mutual enterprise sector to the State's development

Project team: Emeritus Professor Tim Mazzarol[1] (Project leader; tim.mazzarol@uwa.edu.au), Professor David Gilchrist[1], Professor Geoffrey Soutar[1], Associate Professor Andrea Gaynor[1], Associate Professor Amin Mugera[1], Mr Peter Wells[2], Dr Bruce Baskerville[1], Ms Amber van Aurich[1].

Collaborating organisations: [1]UWA; [2]Co-operatives WA; [3]CERU.

Founded in 1933, CBH Group is one of the largest bulk handling and grain storage organisations in the world and one of Australia's largest grain marketers and exporters, with capacity to receive from growers over 21 million tonnes of grain annually through its network of over 100 receival sites. This study fills existing gaps in the historical record regarding the economic and social contributions of the CME sector to WA. Indeed, the history of CBH Group provides an example of how a well-managed co-operative can deliver significant economic and social benefits to its communities.

As a producer co-operative CBH Group has provided essential infrastructure and associated services to the grain industry of WA enabling the expansion, successful development, and sustainability of the Wheatbelt. In addition, it provides evidence which can shape policy debate, particularly the impact of legislation and policy decisions by governments for over 90+ years. For example, the impact of deregulation in the grain industry during the 1980s and 1990s was significant for CBH Group and the sector overall.

The ongoing project conducts research on co-operatives and mutual enterprises (CMEs) in a variety of WA industries, including the agricultural sector.

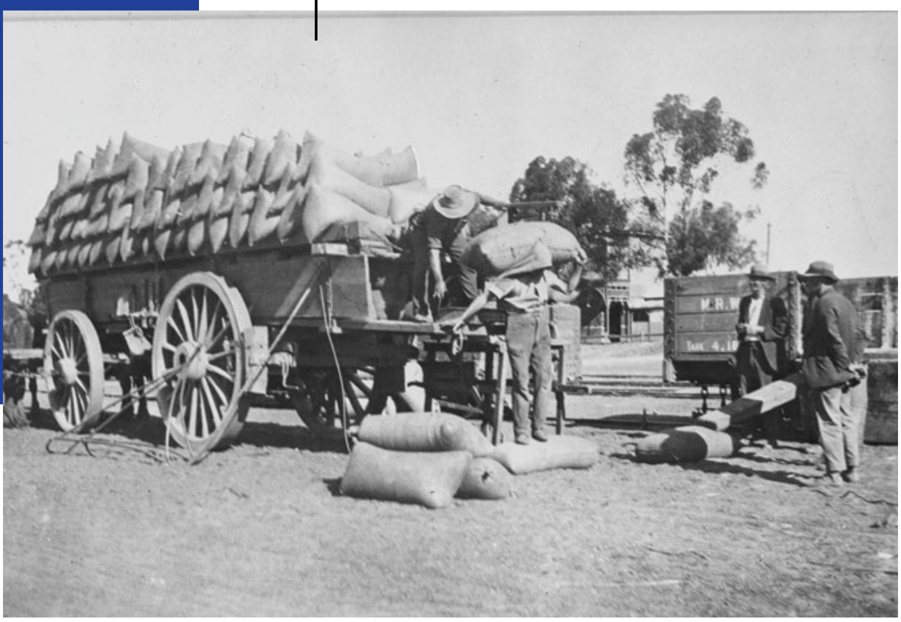
As a part of this project, the team published several case studies, including Co-operative Bulk Handling Ltd. – Handling the Future and Growing Together, 1933-2024. This study examined the history of CBH Group and its contributions to WA—including WA grain growers—delivering new insights to gain understanding and appreciation of the CME sector.

Beyond case studies, the research team has engaged with industry and academic audiences through workshops and conferences. These include governance discussions with GROWCO, presentations at the Co-operatives WA AGM conference and the 59th WA State History Conference, and collaborations with the Business Council of Co-operatives and Mutuals. Additionally, project leader Tim Mazzarol has delivered CME programs in partnership with AIM WA and the UWA Business School, with Executive Education sessions held in May and July 2024.

Tim Mazzarol has also authored Co-operative and Mutual Enterprises Research: A Comprehensive Overview (2024, Routledge), providing an expert synthesis of contemporary CME research. The book explores the historical evolution of the field, foundational theories, and the structure and impact of CMEs, offering a systematic review from enterprise, systems, and member perspectives.

This research is supported by UWA, ARC and industry partners: CBH Group, Capricorn Society Ltd, United Crate Co-operative Ltd, Mount Barker Ltd, Wesfarmers Ltd, The Royal Automobile Club of WA Inc.

Loading or unloading a wagon, ca. 1910 (Courtesy of SLWA).



Cunderdin, 1951 (Courtesy of CBH Group).

Effects of fertiliser subsidies on household maize yields: evidence from Northern, Muchinga, and Luapula provinces, Zambia

Project team: Mr Caleb Siamalambo[2] (Project leader; calebws@gmail.com), Associate Professor Amin Mugera[1].

Collaborating organisations:

[1]UWA; [2] Ministry of Fisheries and Livestock, Zambia; [3]Indaba Agricultural Policy Research Institute, Zambia.

The Government of the Republic of Zambia implements a Farmer Input Support Program (FISP) to enhance food security and reduce poverty. The program consumes three-quarters of Zambia's annual agricultural sector budget. While previous studies have assessed FISP's impact on maize yields, little attention has been given to whether its effectiveness depends on targeting vulnerable smallholder farmers.

This study examines maize yield differences between rural households that received fertiliser subsidies and those that did not.

Data is drawn from the 2019 Rural Agricultural Livelihoods Survey, covering rural households across Zambia's ten provinces. The analysis focused on 522 households in Luapula, Northern, and Muchinga provinces due to their similar climatic conditions and agricultural practices, such as shifting cultivation. To address selection bias, the endogenous switching regression model was used to evaluate treatment effects.

Results indicate that proper targeting is essential for maximizing FISP's benefits. Non-participating farmers would have achieved significantly higher yields if included in the program, while participating farmers would have been better off without the subsidy. This suggests inefficiencies in how subsidies are allocated.

To improve targeting, it is recommended reintroducing the electronic voucher (e-voucher) system, which links farmers to the subsidy using their national registration number. This system can be designed to ensure that farmers graduate from the program after three consecutive years, preventing long-term dependency and enhancing efficiency.

Improved monitoring through digital tracking will ensure resources reach the most vulnerable, ultimately increasing productivity and better aligning FISP with its intended goals.

This research is supported by Australian Award Scholarship.

Associate Professor Amin Mugera with Mr Caleb Siamalambo during his visit to UWA.

The effect of outsourcing agricultural fertiliser mechanization services on wheat production: insights from China

Project team: Jiaojiao Ding[2] (Project leader; dingjiaojiao@cau.edu.cn), Professor Xia Zhao[2], Associate Professor Amin Mugera[1].

Collaborating organisations: [1]UWA; [2]China Agricultural University, China.

Agricultural mechanization services (AMS) play a crucial role in promoting sustainable agricultural development. However, the impact of outsourcing fertiliser mechanization services (FMS) to different types of service providers remains underexplored.

This study examines both the determinants and effects of outsourcing FMS for fertiliser application in rural China.

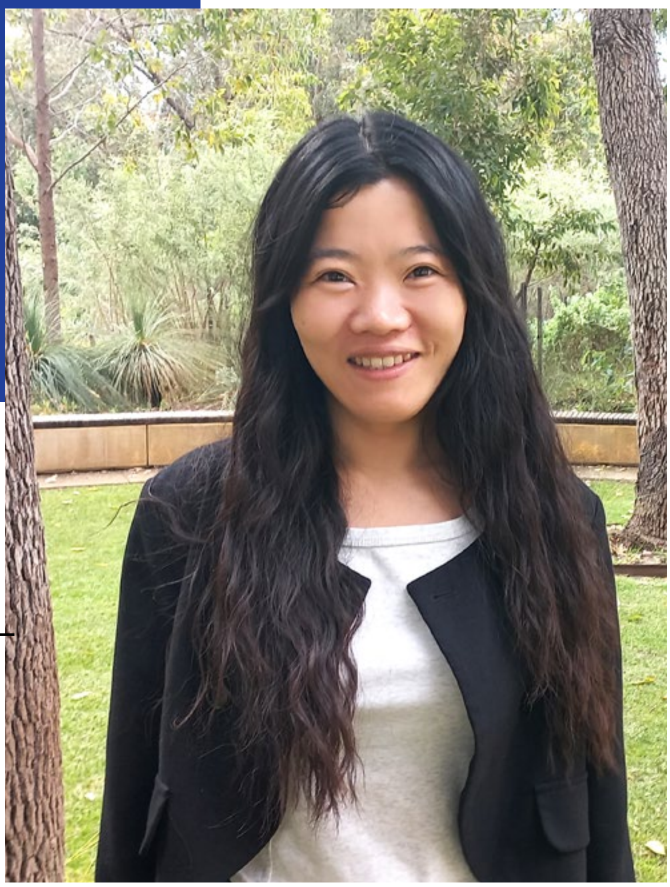
Using a multinomial endogenous treatment effects model to address selection bias and endogeneity, we analysed cross-sectional survey data from 993 wheat producers. The data was collected in 2022 using a rural survey on wheat farmers in the Shandong, Hebei, Henan and Shanxi provinces in the northern region of China.

The findings indicate that the decision to outsource FMS is influenced by farm household characteristics (gender, education, off-farm employment, and risk attitude), farm-specific factors (farm size, land topography, and soil fertility), cooperative membership, and the development of AMS rental markets at the village level.

The results suggest a reduction in fertiliser application by at least 6.6% when farmers outsource fertiliser mechanization services. The combined outsourcing of both fertiliser mechanization services and fertiliser leads to even greater reduction. Additionally, outsourcing to organizational providers has a stronger effect on reducing fertiliser application and improving yields compared to outsourcing to individual service providers.

These findings have significant policy implications for promoting agri-environmental sustainability by improving the efficiency of fertiliser use in the agricultural sector.

This research is supported by CSC.



Ms Jioajiao Ding, Visiting PhD scholar from China Agricultural University.

Traceability of Australian Grains' Sustainability Credentials: Economic Pathways for Future Value Creation

A team of UWA researchers and PhD students at the 2025 Australasian Agricultural and Resource Economics Society conference in Brisbane.

Project team: Emanuel Gomez[1] (Project leader; emanuel.gomez@research.uwa.edu.au), Associate Professor Michael Burton[1], Associate Professor Amin Mugera[1], Professor Ross Kingwell[1], Adjunct Senior Lecturer David Vanzetti[1].

Collaborating organisations: [1]UWA; [2]AEGIC; [3]CBH.

Australia's agricultural sector is widely recognized for its strong sustainability credentials. However, proving these claims remains challenging due to limited transparency in metrics, methodologies, and verification channels. This underscores the need to link sustainability claims with robust traceability systems that enable reliable verification.

To address this challenge, a comprehensive supply chain analysis of Western Australia's grain industry was conducted with the aim of evaluating the feasibility and implications of using traceability systems (TSs) to verify sustainability claims. The study began with an examination of primary producers' views and intentions regarding the adoption of TSs in grain production. These systems would enable grain buyers and other supply chain stakeholders to access verifiable evidence supporting claims made on a defined traceable grain unit. In practical terms, a grower could share information aligned with industry standards to substantiate claims such as, the carbon emissions intensity of grain delivered to an elevator.

Findings from a farm survey in Western Australia indicate that growers recognize value in adopting TSs, with 65% of respondents believing this could generate industry-wide benefits. Much of this perceived value is attributed to the potential to enhance the traceability of food sustainability credentials in response to rising consumer demand (53%) and to support sustainability-linked audits (67%).

However, several factors were identified as potential barriers to adoption. The most significant include the increased data collection efforts required for implementing TSs (72%) and a lack of technological skills (67%), indicating concerns that adoption may demand advanced digital proficiency. Additional barriers cited include investment risks (40%), with some growers questioning whether the return on investment would justify the cost, and data security concerns (70%), reflecting widespread hesitation about potential breaches despite security measures. A more detailed report of this study is available on the Grower Group Alliance website.

As part of the supply chain analysis, a consumer survey was conducted in two key markets for Australian grains: the domestic market and Indonesia. The survey aimed to assess consumer preferences for sustainability-related attributes in food products. Given that instant noodles account for the largest share of wheat imports into Indonesia, this product was used as a reference to evaluate preferences for sustainability certifications, carbon emissions from production, raw material origin, and levels of traceability—from country-level to specific groups of farms. A similar survey design was implemented in Australia, where consumers were presented with bread options featuring these same sustainability and traceability attributes.

The survey included Australia's five largest cities and seven urban locations in Indonesia, with 1,000 respondents in each country.

Preliminary findings reveal distinct consumer demand segments, including groups willing to pay a premium for specific sustainability attributes. While analysis is ongoing, these insights are expected to inform value-creation pathways and support efforts to strengthen traceability and sustainability within Western Australia's grain industry.

This research is supported by the GGA, SW WA Hub and GRDC.

Adopting dairy climate-smart practices in Kenya: the role of practice clusters among smallholder farmers

Mercy Mburu.

Project team: Mercy Mburu[2] (Project leader; mercyn@uonbi.ac.ke), Professor John Mburu[2], Associate Professor Amin Mugera[1], Professor Rose Nyikal[2], Dr Oghaiki Asaah Ndambi[3].

Collaborating organisations: [1]UWA; [2]Department of Agricultural Economics, University of Nairobi; [3]Wageningen University and Research, the Netherlands.

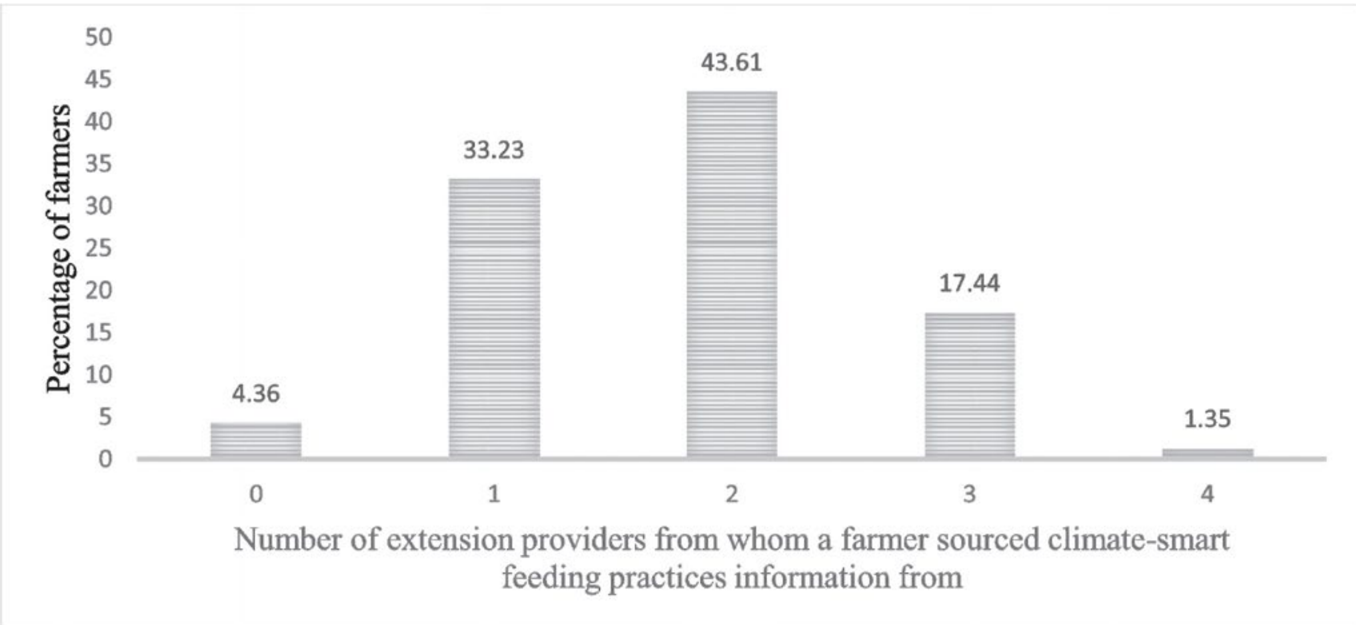
Dairy farmers in developing countries often adopt a combination of different dairy climate-smart (CS) practices to cope with multiple climate variability-induced challenges. However, few empirical studies have evaluated the adoption of the available different clusters of CS practices, the factors influencing cluster choice, and the effects of these clusters on household welfare.

This study analysed survey data from 665 smallholder dairy farmers in Kenya to investigate the welfare effects of adopting seventeen CS practices grouped into four dominant clusters using latent class analysis. A multinomial endogenous treatment effects model was employed to estimate the effect of adopting the four clusters on milk yield and production costs while accounting for selection bias and endogeneity from both observed and unobserved heterogeneity.

The key finding is that the likelihood of adopting any of the four dominant clusters of CS practices depends on farmers' access to extension services, the diversity of service providers, and the frequency of extension contacts. There are significant differences in milk yield and production costs across the four dominant clusters.

The study highlights the importance of policies that promote the provision of extension services by multiple service providers to enhance farmers' resilience and productivity.

This research is supported by the Kenya Climate Smart Agriculture Project (KCSAP) with support from the Government of Kenya, the World Bank and the Africa Milk Project.



Assessment of socio-economic determinants and impacts of climate-smart feeding practices in the Kenyan dairy sector.

Role of agricultural extension in promoting adoption and intensification of underutilised climate-smart dairy practices in Kenya

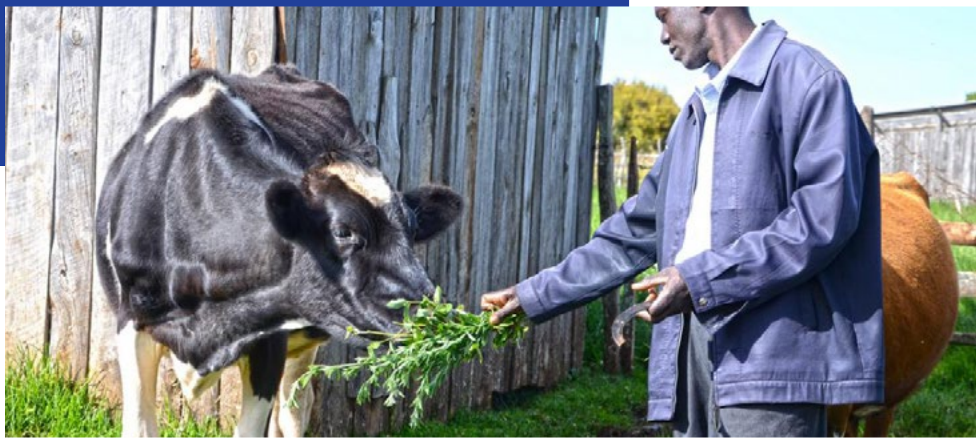
Project team: Mercy Mburu[2] (Project leader; mercyn@uonbi.ac.ke), Professor John Mburu[2], Associate Professor Amin Mugera[1], Professor Rose Nyikal[2], Dr Oghaiki Asaah Ndambi[3].

Collaborating organisations: [1]UWA; [2]Department of Agricultural Economics, University of Nairobi; Kenya; [3]Wageningen University and Research, the Netherlands.

Adoption of dairy climate-smart practices (DCSPs) remains low among Kenyan farmers, despite their potential to improve resilience against the worsening impacts of climate change. This study investigates the factors influencing the learning phase that precedes adoption, as well as the determinants of both uptake and intensity of adoption of the least adopted DCSPs. Using a triple hurdle model and data from 665 dairy farmers across selected counties in Kenya, the research reveals that while learning significantly supports adoption, actual intensive use of DCSPs remains minimal.

Kenya's dairy sector, heavily reliant on rain-fed agriculture, faces mounting challenges due to climate variability, including increased disease prevalence, feed shortages and water scarcity. In response, various DCSPs—ranging from improved feeding strategies and manure management to genetic enhancement—have been promoted. Yet, uptake is hindered by limited understanding and inconsistent use, especially under a pluralistic extension system involving both public and private actors.

The findings highlight that ease of accessing extension services and active milk market participation positively influence learning. Adoption and intensity are significantly boosted when farmers keep records, improve their knowledge of climate change, and engage in frequent extension visits. Perceptions of DCSPs enhancing farm resilience, higher education levels, larger herds, and stronger market engagement also correlate with intensified adoption. Conversely, primary reliance on farming as an occupation was linked to lower intensity, possibly due to risk aversion or limited resources.



The study underscores that learning, facilitated by diverse extension services, is a critical precursor to DCSP adoption. However, adoption alone is not enough; intensity of use must be addressed to realise full benefits. Policymakers are encouraged to strengthen pluralistic extension systems, enhance farmer training, promote record-keeping, and support market access. Researchers should also ensure DCSPs are aligned with tangible improvements in farm resilience. Ultimately, these efforts will support climate action targets and bolster food security in vulnerable regions.

This research is supported by Kenya Climate Smart Agriculture Project (KCSAP) with support from the Government of Kenya, the World Bank and the Africa Milk Project.

Top image: Dairy Cow in Kenya. Photo by S. Odeyo (ICRAF).

Bottom image: Livestock breeders show in Kenya. Actors in the Kenya dairy sector, from dairy farmers to processors and from both the public and private sectors, are moving forward on climate change mitigation. Photo by P. Karaimu (ILRI).

Yadav Padhyoti in a grain field.

Yadav Padhyoti working.

Inefficiencies in Australian grain markets

Project team: Yadav Padhyoti[1] (Project leader; yadav.padhyoti@research.uwa.edu.au), Associate Professor Benedict White[1], Associate Professor Amin Mugera[1], Dr Fiona Dempster[1].

Collaborating organisations: [1]UWA; BITA.

The Australian grain marketing system has evolved significantly since the deregulation of the Australian Wheat Board (AWB) in 2008. Prior to deregulation, the AWB was the sole buyer of Australian grain. The entry of multiple buyers into the market has since fostered competition. Additionally, private firms have introduced online grain trading platforms to enhance market access and transparency. Despite these developments, the uptake on online grain trading is still very low as most producers continue to sell their grain to a few dominant companies. The market for grain buyers is highly concentrated, raising concerns about transparency and efficiency in grain trading.

This research project tested for the weak form of market efficiency, which posits that current prices fully reflect past price information, making it impossible to predict present prices based on historical trends. We analysed daily wheat spot prices over a ten-year period from six Australian ports: Geraldton, Kwinana, Albany, Esperance, Port Adelaide, and Geelong. Using a comprehensive suite of conventional and advanced econometric tests, it was found that past price information does, in fact, predict current prices in all six port markets. This evidence rejects the weak-form efficiency hypothesis, suggesting potential market inefficiencies in the transmission of price information.

The findings suggest that the Australian grain market may not be functioning optimally, potentially benefiting technically adept large traders while disadvantaging producers and consumers. This highlights the need for policy interventions to promote equitable access to market information.

The results should be interpreted with caution as they are specific to the six port markets studied. Further research would explore the extent and direction of the Australian grain market's response to international market price fluctuations, providing insight into the impact of trader behaviour on producer welfare. Additionally, given that modern marketing systems, such as online trading platforms, can enhance efficiency by improving access to timely and accurate information, futures studies could investigate the barriers preventing Australian producers from adopting these platforms.

This research is supported by UWA and BITA.

International Agricultural Development Initiatives

Intercropping Project Inception Workshop.

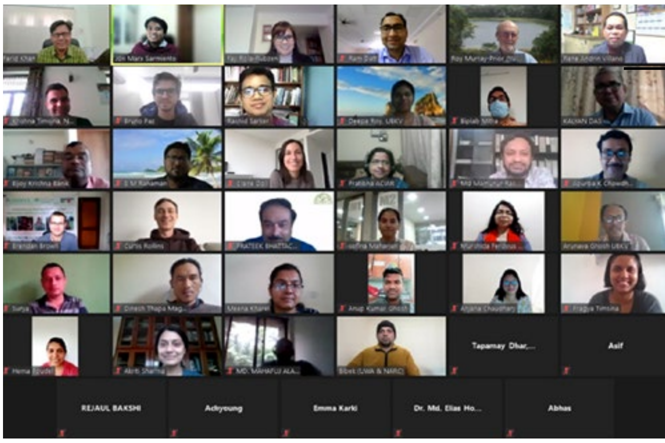
Project team: Associate Professor Fay Rola-Rubzen[1] (Project leader; fay.rola-rubzen@uwa.edu.au), Dr Sofina Maharjan[1], Dr Jon Sarmiento[1], Ms Tammie Harold[1], Dr Bruno Paz[1], Dr Hue Thi Vuong[1], Dr Claire Doll[1], Dr Curtis Rollins[1], Dr Dinesh Thapa[1], Dr Roy Murray-Prior[2], Dr Krishna P. Timsina[3], Dr Md Mahafuj Alam[4], Dr Alison Laing[5], Professor Renato Villano[6], Professor Kalyan K. Das[7], Associate Professor Md Farid Uddin Khan[8], Associate Professor S.M. Rahaman[9].

Collaborating organisations: [1]UWA; [2]Agribiz RD&E Services; [3]Nepal Agricultural Research Council; [4]RDRS Bangladesh; [5]CIMMYT (Bangladesh); UNE, UK; [7]Uttar Banga Krishi Viswavidyalaya; [8]Rajshahi University; [9]Bihar Agricultural University; CSIRO; National University of Timor Lorosa'e, Timor-Leste.

In 2024, Associate Professor Fay Rola-Rubzen led several multidisciplinary research initiatives focused on agricultural and behavioural economics across South and Southeast Asia. Her work, funded by the Australian Centre for International Agricultural Research (ACIAR), has centred on improving smallholder livelihoods, gender inclusivity, and sustainable rural transformation in developing nations.

A flagship initiative, the Farmer Behaviour Insights Project, investigated farm household decision-making in the Eastern Gangetic Plains of Bangladesh, India, and Nepal. By applying behavioural economics, the project explored why adoption of conservation agriculture remains low despite its proven benefits. The research provided critical insights into how gender, risk perception, and socio-economic conditions influence decision-making, helping design more effective, farmer-centred extension services.

Complementing this, the Sustainable and Resilient Farming Systems Intensification (SRFSI) project examined how risk attitudes affect adoption of conservation agriculture-based sustainable intensification (CASI) technologies. Findings from both projects have been published in high-impact journals, including the Journal of Agriculture and Environment for International Development and the Australian Journal of Agricultural and Resource Economics.



ZOOM meetings with the international collaborators.

The Additive Intercropping Project focused on improving productivity and sustainability of wide-row crops like maize through high-value intercrops in Bangladesh, Bhutan, and eastern India. This approach offers potential benefits such as enhanced soil health, improved household nutrition, and increased gender equity. The project addresses agronomic, socio-economic, and institutional challenges to promote adoption at scale.

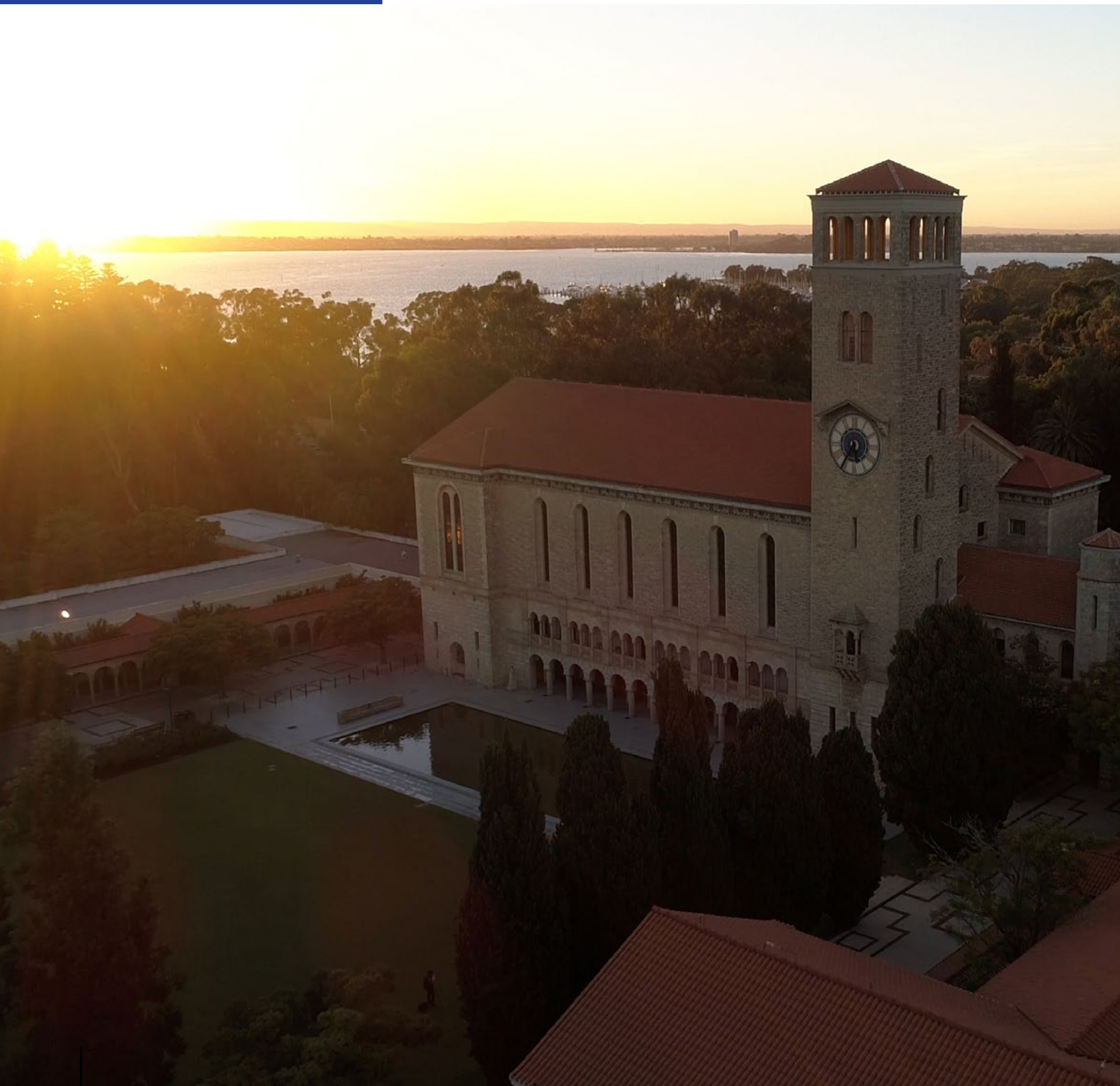
Another major research explored the drivers of inclusive rural transformation across Bangladesh, China, Indonesia, and Pakistan. It examined the roles of non-farm employment, infrastructure, education, and gender inclusion in shaping rural change. Findings from this work inform evidence-based policy advice and have been featured in top-tier journals such as Sustainable Development and Journal of Integrative Agriculture.

In addition to these major projects, Fay contributed to several smaller, yet impactful, initiatives. These include research on the impact of COVID-19 on vegetable farmers in Timor-Leste; barriers to smart farming adoption in Malaysia; drivers of labour migration in Nepal; and institutional factors influencing soil fertility management in Pakistan. PhD-led studies under her supervision, such as those on cooperative contract farming in the Philippines and rural migration dynamics in Nepal, further contribute to capacity building and knowledge generation in the region.

Associate Professor Fay Rola-Rubzen presenting research on gender and rural transformation at Peking University.

Across all projects, a strong emphasis on gender mainstreaming, local capacity building, and farmer-centric approaches underscores Fay's commitment to inclusive and sustainable agricultural development. The breadth and impact of this work not only advance academic understanding but also offer practical solutions for policymakers and development agencies working to improve the resilience and prosperity of smallholder farming communities.

This research is supported by ACIAR

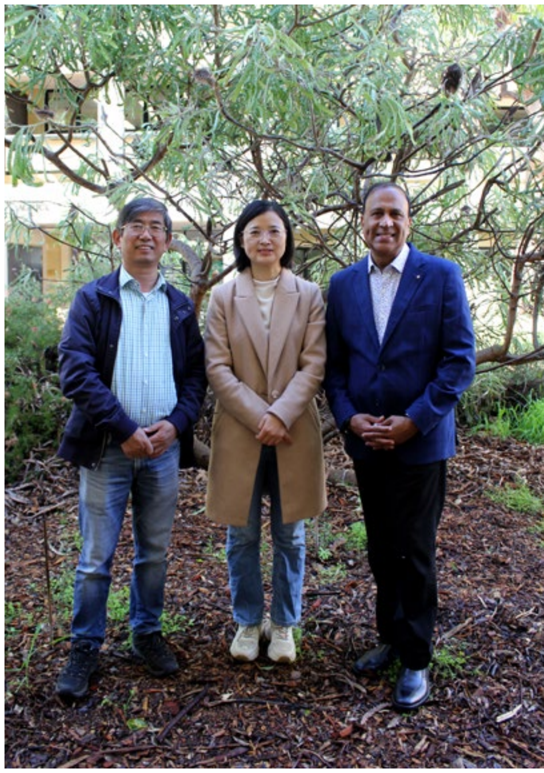


7

Education and Outreach Activities

Strengthening communication links with industry, farmer groups and the broader regional and international 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.

Front cover and inside spread of the April 2024 newsletter.



Dr Sheng Chen, Professor Jun Zou and Hackett Professor Kadambot Siddique.

Newsletters

IOA's broad range of activities are regularly captured through its newsletter. 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.

The newsletter serves as a record of IOA's research activities and captures recently funded projects, research achievements, new staff and students, events and, importantly, a list of newly published peer-reviewed journal articles in agriculture and related areas.

Published three times per year in April, August and December, the newsletter is circulated widely in electronic format and hardcopy to more than 6000 readers.

Online presence

Our website provides an overview of the IOA 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 website along with a repository of the latest media statements, research and general news. Documents such as the Strategic Plan, Annual Research Report and newsletters are also readily available to view and download.

In 2024, IOA's social media audience increased significantly. LinkedIn once again had the fastest growing audience, with 2,320 new followers. Thirteen event videos published to YouTube in 2024 amassed more than 3,352 views. More than 160 people were subscribed to the YouTube channel by the end of 2024. The @IOA_UWA X (formerly Twitter) gained 259 more followers to end the year with an audience of 3,489. Given the ethical implications of the now Elon Musk-owned X, many researchers have been moving towards a new platform BlueSky. IOA started a BlueSky account and posts similar content as on X.

Visitors to IOA

Interactions with members of like-minded institutions, universities, government, and the agricultural industry and community are critical to knowledge sharing and strengthening our research links and collaborations. Throughout 2024, IOA hosted more than 60 individuals from local, national and international organisations at the Crawley campus.

In May, Professor Jim Kinsella, from University College Dublin, visited UWA to deliver a special lecture co-hosted by the Institute of Agriculture and the School of Agriculture and Environment. While touring UWA Farm Ridgefield, he reflected on the stark differences between Irish and Australian farming systems.

In August, CGIAR Executive Managing Director Dr Ismahane Elouafi visited UWA in August to deliver the 30th Hector and Andrew Stewart Memorial Lecture. She toured the UWA glasshouses and The UWA Farm Ridgefield, where she interacted with research students presenting their projects.

In September, a delegation from Nagoya University, led by IOA, toured CSBP Fertilisers' Kwinana works as part of their international study visit. Highlights included exploring the Superphosphate Manufacturing Plant, CSBP's storage and despatch network, and enjoying panoramic views from a Flexi-N storage tank.

In October, WA Governor Christopher Dawson and his wife, Darrilyn Dawson, visited UWA Farm Ridgefield to explore sustainable farming systems and discuss key issues like food security and climate change. Hosted by UWA leaders and researchers, the visit included a farm tour and discussions on strengthening ties between government, education, and agriculture.

A deeply rewarding two-month GRDC visiting research fellowship spent at IOA culminated in Huazhong Agricultural University Professor Jun Zou delivering a special lecture on her latest research. Professor Zou presented on 'Genome-wide reconstruction of a de novo domesticated diverse synthetic Brassica napus population' at the Alan Robson Agriculture Lecture Theatre.

Photos (clockwise from top left):

The Nagoya University delegation during the UWA Global Engagement Office's Matsuri festival celebrations, which was attended by the Consul-General of Japan Naito Yasushi.

Hackett Professor Kadambot H.M. Siddique, Dr Ismahane Elouafi and Tim Watts in the field at Ridgefield.

The visiting group during their tour of The UWA Farm Ridgefield, with the Governor pictured at the centre.

Visitors to IOA

Name of visitor	Visitor's organisation and country	Host details	Dates of visit
Xiaoke Ping	Southwest University, China	The UWA Institute of Agriculture	January 2024 – January 2025
Andrew Doecke	Omnia Specialities Australia	UWA School of Agriculture and Environment & The UWA Institute of Agriculture	23 February
Duncan Hickman	Tektonex Ltd, Australia	Dr Dilusha Silva & The UWA Institute of Agriculture	4 April
Dr Elizabeth Jackson	Curtin University, WA, Australia	UWA School of Agriculture and Environment & The UWA Institute of Agriculture	24 April
Professor Liz Jackson	Curtin University, WA, Australia	The UWA Institute of Agriculture & UWA School of Agriculture and Environment	April 2024
Marion Lewis	The Livestock Collective, Australia	The UWA Institute of Agriculture & UWA School of Agriculture and Environment	April 2024
Professor Jim Kinsella	University College Dublin, Ireland	The UWA Institute of Agriculture & UWA School of Agriculture and Environment	May 2024
Dr Iqbal Khan	Jamia Hamdard, India	The UWA Institute of Agriculture	May 2024
Dr Tony Irawan Professor Yusman Syaukat Professor Hermanto Siregar Professor Lukytawati Anggraeni	Institut Pertanian Bogor, Indonesia	Associate Professor Fay Rola-Rubzen	May 2024
Mukhamad Najib	Education and Culture Attaché, Indonesian Embassy	Associate Professor Fay Rola-Rubzen	May 2024
Professor Madya Dr Kay Dora Abd Ghani Dr Wan Liza Md Amin Dr Tay Chia Chay Dr Mohd Ikmal Fazlan Rozli	Universiti Teknologi Mara, Malaysia	Associate Professor Fay Rola-Rubzen	May 2024
Dr Richard Smith	Perth, WA, Australia	The UWA Institute of Agriculture	June 2024
Mathis Calvel	Purpan Ecole D'Ingenieurs, France	The UWA Institute of Agriculture	June – September 2024
Dr Michael Crawford	CRC for High Performance Soils, Australia	The UWA Institute of Agriculture	July 2024
The Hon. Reece Whitby MLA	WA Minister for Energy, Environment, and Climate Action, Australia	The UWA Institute of Agriculture	July 2024
Heidi Mippy	Curtin University, WA, Australia	The UWA Institute of Agriculture	July 2024
Tony Seabrook	Pastoralists and Graziers Association, WA, Australia	The UWA Institute of Agriculture	July 2024
Rob Grima	Planfarm, WA, Australia	The UWA Institute of Agriculture	July 2024
Debbie Dowden	Challa Station, WA, Australia	The UWA Institute of Agriculture	July 2024
Peter Metcalfe	Inter.Earth, WA, Australia	The UWA Institute of Agriculture	July 2024
Rebecca Kelly	Mingenew, WA, Australia	The UWA Institute of Agriculture	July 2024
Richard Brake	Richard Brake Consulting, WA, Australia	The UWA Institute of Agriculture	July 2024
Dr Ismahane Elouafi	CGIAR, France	The UWA Institute of Agriculture	August 2024

Name of visitor	Visitor's organisation and country	Host details	Dates of visit
Dr Jun Zou	Huazhong Agricultural University, China	The UWA Institute of Agriculture & GRDC	August – September 2024
Nagoya University Study Tour – eight students, 1 academic.	Nagoya University, Japan	The UWA Institute of Agriculture	September 2024
Professor Xinhua He	Sichuan Agricultural University, China	The UWA Institute of Agriculture	September 2024
Dr GP Singh Dr Vijay Rana Dr Sundeep Kumar	Indian Council of Agricultural Research (ICAR) - National Bureau of Plant Genetic Resources, India	The UWA Institute of Agriculture	September 2024
Dr Girish Jha Dr Jyoti Kumari Dr Neeraj Budhlakoti	ICAR-Indian Agricultural Statistics Research Institute, India	The UWA Institute of Agriculture	September 2024
Dr PK Bhati Dr Manish Vishwakarma	Borlaug Institute for South Asia, Ludhiana	The UWA Institute of Agriculture	September 2024
WA Governor His Excellency the Honourable Christopher Dawson AC APM Darrilyn Dawson	Government House, Australia	The UWA Institute of Agriculture & Farm Manager Tim Watts	September 2024
Jackie McBurney Andrew Dover	Shire of Pingelly, WA, Australia	The UWA Institute of Agriculture & Farm Manager Tim Watts	September 2024
Dr David Dent	University of Surrey, UK	The UWA Institute of Agriculture & Institute of Advanced Studies	October 2024
Dr Hima Bindu Kudapa	International Crops Research Institute for the Semi-Arid Tropics, India	The UWA Institute of Agriculture	October 2024
Dr Frank Grosse Dr Olaf Sass Dr Urs Fischer Christoph Betschart	NPZ, Germany	The UWA Institute of Agriculture & Professor Wallace Cowling	October 2024
Professor Ndiko Ludidi	University of Mpumalanga, South Africa	The UWA Institute of Agriculture	November 2024
Chris Gazey	DPIRD, Australia	UWA School of Agriculture and Environment & The UWA Institute of Agriculture	November 2024
Stuart McAlpine	Buntine, Australia	UWA School of Agriculture and Environment & The UWA Institute of Agriculture	November 2024
Dr Mark Farrell	CSIRO Adelaide, SA, Australia	UWA School of Agriculture and Environment & The UWA Institute of Agriculture	November 2024
Professor Deqiang Zhang Professor Qiaoxia Shang Professor Demei Li Associate Professor Xiaoxi Jin	Beijing University of Agriculture, China	UWA School of Agriculture and Environment & The UWA Institute of Agriculture	November 2024
Professor Ferdous Sohel	Murdoch University, WA, Australia	The UWA Institute of Agriculture	November 2024

Professor Senthold Asseng delivering his lecture.

Spectral variations for vegetation vitality

While it may seem far-fetched, Professor of Digital Agriculture Senthold Asseng has shown that wheat grown in indoor vertical structures under optimised growing conditions can result in several hundred times higher yields than in the field.

It could also lead to several harvests per year, use less land, be independent of climate, reuse most water, exclude pests and diseases, and have no nutrient losses to the environment.

Professor Asseng, who is the Director of the World Agricultural Systems Center at the Technical University of Munich in Germany, delivered a special public lecture for IOA in March.

“It is clear that the world needs to produce more healthy food with less environmental impact, whilst overcoming the challenges of climate change,” he told the 120-strong audience.

As food demand continues to increase alongside a growing global population, Dr Asseng emphasised that environmental degradation, high water use, pesticide applications, nutrient pollution and biodiversity loss had rendered many current cropping systems unsustainable.

His lecture explored how automation and controlled-environment food production offered massive productivity gains with reduced environmental impact.

Pingelly workshop gets down to earth

Leading experts in soil science, farming systems, economics, biotechnology, and waste-to-value innovations gathered at a UWA workshop on Principles of Soil Health & Profitable Agriculture in July. Held in Pingelly, the workshop aimed to engage a diverse audience, including the local farming community and those connected to the nearby UWA Farm Ridgefield.

Approximately 30 farmers, public and industry partners, agriculture consultants, scientists, and research students attended the event. Organised by Emerita Professor Lynette Abbott and Dr. Hira Shaukat, the workshop focused on the critical intersection of soil health and agricultural profitability. Topics covered included the principles of soil health, understanding soil biology in the context of profitable crops, soil health benefits, carbon sequestration, the economics of low-input mixed farming systems, and the role of the circular economy in sustainable agriculture.

The event also included open forums for panel discussions, fostering interactive dialogue between participants and experts. Topics discussed included defining healthy soil, testing for transitions, minimizing risks, evaluating success in early stages of practice changes, and considerations before purchasing soil inoculants.

Speakers included Emerita Professor Lyn Abbott, Hackett Professor Kadambot Siddique, Professor Nanthi Bolan, Dr Margaret Roper, Bradley Plunkett, Dr Bede Mickan, Dr Sasha Jenkins, and Phil Barrett Lennard.

The workshop was funded by the Australian Government Department of Agriculture, Fisheries and Forestry, UWA, DPIRD, and the FutureCarbon13 project.

A group of workshop attendees outside the Pingelly Recreation & Cultural Centre.

Postgraduate Showcase: shaping the future of food security at UWA

The focus of The UWA Institute of Agriculture's 2024 Postgraduate Showcase was the critical role of graduate research in shaping the future of food security, innovation, and agricultural sustainability. Head of the UWA School of Social Sciences, Professor Amanda Davies, addressed the audience of nearly 100 people, emphasizing the importance of postgraduate research in driving change.

"Graduate research is special because it's intensive, utilizing new methods and accessing new ideas that are difficult to implement in other settings," Professor Davies said, highlighting the value of focused research in addressing global challenges.

Institute Director Hackett Professor Kadambot Siddique reflected on the 18th annual event, noting the growth of the showcase over the years.

The first session, chaired by Dr Abbie Rogers, Co-Director of the UWA Centre for Environmental Economics and Policy, began with Sneha Priya Pappula Reddy, who presented her research on the physiological and molecular basis of drought tolerance in chickpeas. Dr. Michael Young followed, sharing his work on farm optimization modelling to improve livestock management in WA's mixed farming businesses. Jessie Weller then explored the geophysical characterization of the Avon River Critical Zone Observatory. Samantha Harvie, from the School of Molecular Sciences, concluded the first session by discussing how nitrogen application timing influences wheat protein composition.

The second session, chaired by Professor Patrick Finnegan, featured Sarah Babington's work on identifying novel biomarkers of sheep welfare. Sharmin Sultana followed with her research on isoflavones in clover honeys, before Felipe Castro Urrea wrapped up the event with his talk on sustainable genetic gains in field pea breeding through genomic selection.

The event showcased the breadth and depth of research being conducted by UWA's postgraduate students, underscoring their contributions to advancing agricultural science.

Postgraduate Showcase student presenters with their mentor Emeritus Professor Graeme Martin (far left) and Hackett Professor Kadambot Siddique.

Jessie Weller presenting at the packed Bayliss Lecture Theatre.

Rob Grima addresses the crowd while introducing the panellists.

Industry Forum

Is net zero in agriculture a pipe dream?

The 2024 UWA Institute of Agriculture's Industry Forum, held in July, attracted more than 270 participants, marking the event's largest turnout in its 18-year history. This year's theme, "Can Agriculture Reach Net Zero?", sparked a highly relevant and engaging discussion on the challenges and potential of reducing emissions in the agricultural sector.

In his keynote address, Dr. Michael Crawford, CEO of the CRC for High Performance Soils, acknowledged the difficulty of achieving net zero across the entire agricultural sector but emphasised the importance of striving for this goal. Dr Crawford highlighted that while some farms or regions might be able to reach net zero for a time, it was unlikely the sector as a whole could do so. Nonetheless, he stressed the importance of making the effort, pointing out the compelling reasons for pursuing such an ambitious target.

The event opened with remarks from the Hon. Reece Whitby MLA, Minister for Energy, Environment, and Climate Action, who underscored the significance of the Forum's theme. Curtin University Indigenous Liaison Manager Heidi Mippy then provided a heartfelt Welcome to Country.

UWA's Professor of Agricultural Economics and DPIRD Chief Economist Ross Kingwell followed with a thought-provoking presentation, addressing the growing challenge of emissions in agriculture. Professor Kingwell noted that while emissions are on the rise, the focus of emissions reduction efforts has shifted from livestock to cropping systems. He remarked that a decade ago, the conversation would have been centred on emissions from livestock, particularly cattle.

Tony Seabrook, President of the Pastoralists and Graziers Association, provided an insightful perspective on the issue, highlighting the environmental impact of other industries, such as cruise ships, which contribute significantly to emissions and waste, yet agriculture often bears the brunt of criticism.

The Forum's discussion panel was moderated by Planfarm agronomy consultant Rob Grima and featured contributions from Challa Station pastoralist Debbie Dowden, Inter.Earth Business Development Manager Peter Metcalfe, 2023 CBH Nuffield scholar Rebecca Kelly, and farm business advisor Richard Brake. The lively exchange of ideas sparked further debate on the possibilities and limitations of achieving net zero emissions within agriculture.

The UWA Institute of Agriculture's annual Industry Forum, supported by CSBP and the Farmers Ltd Jubilee of Agriculture Science Fellowship, continues to provide a critical platform for engaging with pressing issues in the agricultural sector, fostering dialogue between industry, academia, and government.

Lecture highlights the role of agricultural extension in shaping future farming

While touring UWA Farm Ridgefield, University College Dublin's Professor Jim Kinsella was struck by the stark contrast in scale between Australian and Irish farming systems.

"Ireland has around 135,000 farms, nearly all family-owned, with an average size of 33.4 hectares," Professor Kinsella explained.

"Ridgefield, at 1600 hectares, is considered relatively modest — in Ireland, we have more small, intensive farming operations."

Despite this contrast, Professor Kinsella highlighted the many similarities between Western Australia and Dublin, particularly their universities' shared goal of strengthening agricultural extension services through postgraduate studies.

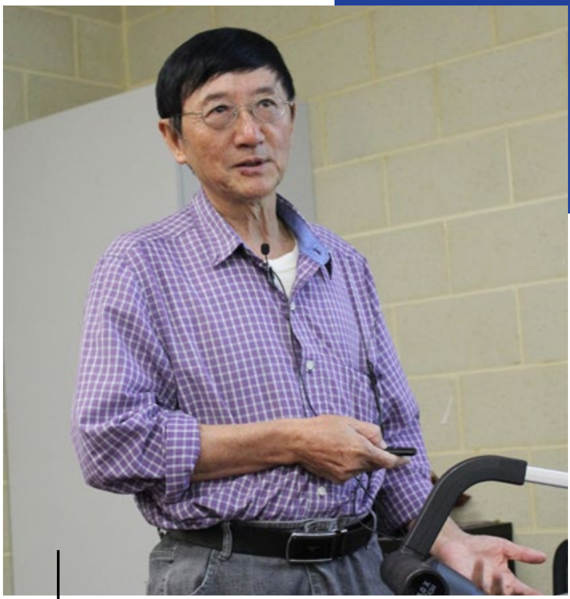
The UWA Institute of Agriculture and the UWA School of Agriculture and Environment co-hosted a special lecture delivered by Professor Kinsella during his month-long visit in May.

In his lecture, he discussed the global neglect of agricultural extension services in teaching and research programs throughout the 1990s and 2000s.

"Today, agriculture graduates are crucial in supporting farm decisions through both public and private extension services," he said.

"Postgraduate agricultural extension programs, such as those delivered at University College Dublin, equip students with the knowledge and capabilities needed for these roles."

Professor Jim Kinsella presenting at Bayliss Lecture Theatre.



Professor Xinhua He presenting his talk in the Alan Robson Agriculture Lecture Theatre.

Shining a light on effects of elevated CO_2 and AMF

Professor Xinhua He, an Endowed Professor from Sichuan Agricultural University, delivered a guest lecture at The UWA Institute of Agriculture on the effects of elevated CO_2 (eCO_2) and arbuscular mycorrhizal fungus (AMF) in intercropping systems.

Focusing on wheat-faba bean intercropping, he discussed how C/N cycling and interplant nutrient movement are influenced under global environmental changes using advanced isotopic and sequencing techniques.

Professor He highlighted the limited research on AMF interactions in intercropping systems, particularly under varying CO_2 conditions. He noted that mycorrhization and eCO_2 have complex, species- or cropping pattern-dependent effects on plant biomass and physiology. His work provides insights into improving plant-soil interactions and productivity under future climate scenarios.

Lecture explores the potential of GABA in plant stress tolerance

While Gamma-Aminobutyric Acid (GABA) is widely recognised as a chemical neurotransmitter in the medical field, Dr Iqbal Khan demonstrated its critical role in plants during a May lecture hosted by the UWA Institute of Agriculture.

In his introduction, Institute Director Hackett Professor Kadambot Siddique shared his connection with Dr Khan, dating back to their first meeting at the 2015 International Plant Physiology Congress in New Delhi.

"Since then, our friendship has grown, and he became an Adjunct Associate Professor with us last year," Professor Siddique said.

"Although I am his mentor, I've gained much from his insights, especially regarding reducing environmental stress in staple crops like wheat and rice. His work addresses the critical funding priorities in India to enhance crop resilience against future climatic challenges."

Dr Khan, an Assistant Professor in the Botany Department and Deputy Director of the Centre for Environment and Sustainable Development at Jamia Hamdard, India, delivered a lecture highlighting his groundbreaking research.

He explored how GABA influences source-sink metabolism, defence mechanisms, and growth under salt stress in wheat plants. His findings hold significant implications for improving agronomic performance in the face of global climate pressures.

Dr Khan's work continues to bridge the gap between plant physiology and sustainable agriculture, providing innovative solutions to address environmental stress in key crops.

"Although I am his mentor, I've gained much from his insights, especially regarding reducing environmental stress in staple crops like wheat and rice. His work addresses the critical funding priorities in India to enhance crop resilience against future climatic challenges."

Professor Kadambot Siddique

Professor Kadambot Siddique and Dr Iqbal Khan (middle) with some attendees following the lecture.

Grounded in greatness: Celebrating five decades of Emerita Professor Abbott at UWA

The UWA community gathered to celebrate Emerita Professor Lynette Abbott's extraordinary five-decade career in soil science and her lasting contributions to UWA and the broader agricultural community.

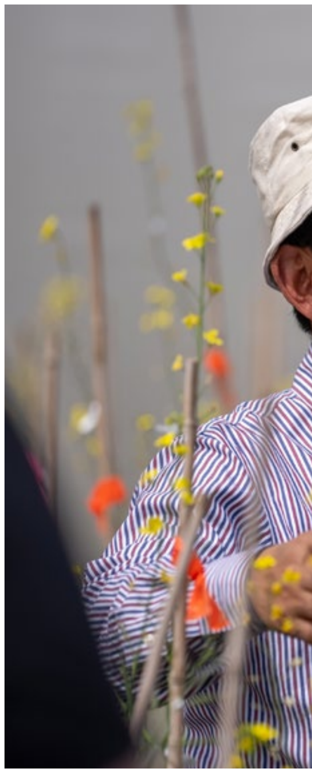
The event featured heartfelt testimonials from colleagues and industry leaders, including the Ag Institute of Australia Chair, Dr Don Burnside, and the President of Soil Science Australia WA, George Mercer. UWA Institute of Agriculture Director Hackett Professor Kadambot Siddique highlighted her significant impact on UWA Farm Ridgefield and beyond.

The symposium showcased presentations on key topics in soil science and agriculture. DPIRD's Chris Gazey shared insights on soil management in WA's broadacre agriculture, while Associate Professor Louise Barton reflected on nitrous oxide emissions from cropping soils. Stuart McAlpine, a fourth-generation farmer and soil health advocate, spoke on the inspiration Professor Abbott has provided to both academia and the field. The program concluded with Professor Abbott herself addressing the audience.

In addition to the formal talks, attendees enjoyed a vibrant garden party in Prescott Court Gardens, organised by UWA's Students of Natural and Agricultural Sciences (SNAGS). The celebration featured dried barley and native flowers as decorations, creating a warm and festive atmosphere. Professor Abbott's brother delivered a moving toast, leading to a rousing three cheers and the cutting of three celebration cakes.

Professor Abbott expressed her gratitude for the event and the people who have supported her throughout her career. She reflected on the friendships, mentorships, and collaborative efforts that defined her time at UWA, leaving an indelible mark on soil science and agricultural research. The day honoured her legacy as a pioneer and mentor, inspiring generations of scientists and students.

The crowd delivers a standing ovation to Emerita Professor Lynette Abbott.



(Left to right) Associate Professor Matthias Leopold, Dr Ben Biddulph, Professor Tim Colmer, the Hon. Jackie Jarvis, Hackett Professor Kadambot Siddique and Cec McConnell.

Shenton Park Field Station 2024 Open Day

In September, UWA Shenton Park Field Station hosted its 2024 Open Day, drawing more than 250 visitors to explore a wide range of innovative research. The event was a collaborative effort between the UWA Institute of Agriculture, UWA School of Agriculture and Environment, School of Engineering, School of Biological Sciences, and School of Molecular Sciences. The day featured six project site demonstrations and four information stalls, offering attendees a comprehensive view of UWA's cutting-edge work in agriculture, environmental science, and engineering.

The formal proceedings began with a welcome address from UWA Senior Deputy Vice-Chancellor Professor Tim Colmer, followed by the Hon Jackie Jarvis MLC, WA Minister for Agriculture and Food, who officially opened the event. Mrs. Jarvis also launched two new annual pasture legumes developed through a joint venture between UWA and DLF Seeds under the Annual Legume Breeding Australia (ALBA) initiative. Hackett Professor Kadambot Siddique, Director of the UWA Institute of Agriculture, emphasized the event's significance in showcasing multidisciplinary research at UWA, highlighting the Field Station's long-standing contribution to scientific and agricultural advancements in Western Australia.

Attendees had the opportunity to explore several key research projects, including InterGrain's innovative work on improving wheat yield potential by combining Australian genetics with gene editing techniques from Inari. The Coastal & Offshore Research Lab also captivated visitors with its applications in marine renewable energy and coastal protection, while the Aquaculture Facility demonstrated the growing importance of aquaculture as a solution to global protein demands. Dr. Sheng Chen's research on improving canola heat tolerance also attracted significant interest, with visitors learning about his GRDC-funded project focused on crop resilience under changing climate conditions.

The event also highlighted the engineering innovations being developed at UWA's Centre for Engineering Innovation: Agriculture & Ecological Restoration (CEI:AgER). Visitors were introduced to engineering solutions aimed at improving agricultural practices and ecological restoration. Additionally, the Animal Care Services team offered a demonstration of how they support UWA's biological and biomedical research projects, while the ARC Centre of Excellence in Plants for Space ran an interactive stall showcasing its research on plant science for space exploration.

The day underscored the importance of collaboration across disciplines, with UWA's various research units joining forces to tackle some of the most pressing challenges in agriculture, food security, and environmental sustainability. The event provided a unique opportunity for researchers to engage with the public, share their findings, and promote further engagement with UWA's mission to drive innovation and knowledge for the future of WA's agriculture and beyond.

Photos (from top):

Dr Sheng Chen presents his research among canola plants in the shadehouse.

A group of people gather in the field plots to hear from ALBA researchers Associate Professor Phillip Nichols and Brad Wintle.

CEI:AgER ecological restoration tech lead Dr Monte Masarei and agricultural tech lead Dr Wesley Moss co-presenting.

Lecture calls for UWA and UMP to join research forces

Professor Ndiko Ludidi, Dean of the Faculty of Agriculture and Natural Sciences at the University of Mpumalanga (UMP), visited the UWA Institute of Agriculture to deliver a lecture on the relevance of plant science research to food system resilience in the face of climate change. He highlighted the shared climate challenges between South Africa and Australia, specifically how climate change poses a significant threat to food security in both countries.

The lecture outlined how South Africa's food systems are being affected by climate change, particularly through issues like drought, heat, and salinity. Professor Ludidi discussed the role of plant diversity, crop genetic diversity, and rhizospheric microorganisms in improving crop adaptation to these challenges. These resources, he explained, could be key in strengthening food systems' resilience to climate impacts.

Professor Ludidi concluded by stressing the potential for collaboration between UMP and UWA. He noted the complementary strengths in agricultural and environmental research at both universities, suggesting that there are valuable synergies to explore. He encouraged future partnerships that could further enhance research and innovation aimed at improving food security in both countries.

Professor Ludidi presenting his lecture at the Alan Robson Agriculture Lecture Theatre.

Hector and Andrew Stewart Memorial Lecture

Dr Ismahane Elouafi delivered the 30th Hector and Andrew Stewart Memorial Lecture at UWA, focusing on the need to transform global food systems to adapt to climate change. In her lecture titled Science & Innovation to Transform Global Food Systems in a Climate Crisis, she discussed the critical challenges faced by agriculture, particularly the impact of climate change on food production.

Dr Elouafi emphasized the importance of integrating science, innovation, and policy to create resilient food systems. "We must connect the dots across agriculture, biodiversity, climate change, and nutrition," she said, highlighting the need for a coordinated approach to address these interconnected issues.

The lecture also stressed the significance of collaboration. "Working and partnering together is the most important factor," Dr Elouafi stated, urging governments, researchers, and donors to unite in their efforts. She pointed out that organizations like ACIAR and the Australian Government play a crucial role in funding research that drives innovation and addresses climate-related challenges in agriculture.

Dr Elouafi's presentation also outlined CGIAR's work in global agricultural research, stressing the importance of sustainable practices that can withstand the pressures of climate change. She encouraged attendees to reflect on how they can contribute to transforming food systems in their own regions.

The Hector and Andrew Stewart Memorial Lecture, held annually in honour of the late Hon. Hector J. Stewart and his son, Andrew M. Stewart, brought together a distinguished audience to hear Dr Elouafi's insights. Her lecture was a compelling reminder of the urgent need for global cooperation in tackling the challenges of climate change and securing a sustainable food future.

Dr Elouafi presenting the 30th Hector and Andrew Memorial Lecture.

Participants on day two of the OzFlux Conference at UWA. Photo by Liena.

UWA hosts OzFlux workshop and conference

UWA hosted the OzFlux workshop and conference, bringing together flux researchers from Australia, New Zealand, and beyond. Despite heavy rain and muddy fields, spirits remained high during a visit to UWA Farm Ridgefield, where participants saw the flux tower and Avon Critical Zone Observatory (CZO) facility in action. The visit took place on the third day of the annual OzFlux Conference, held at UWA's Crawley campus, supported by the Terrestrial Ecosystem Research Network (TERN).

OzFlux, a network of micrometeorological flux researchers from Australia and New Zealand, is part of the global FLUXNET network, which operates flux towers to measure the exchange of carbon dioxide, water vapour, and energy between ecosystems and the atmosphere.
The conference included two days of talks across various themes, including agroecosystem measurement, ecological applications of flux science, and advances in measurement techniques. Participants from research institutions, government, and industry, along with international delegates from Japan, China, Indonesia, and Europe, engaged in the discussions both in person and online.

On the first day, Institute Director Hackett Professor Kadambot Siddique gave an overview of UWA Farm Ridgefield and the Best Practice Farming Systems Project. The second day featured a career advice session for early career researchers, with a panel including TERN director Dr Beryl Morris, OzFlux director Professor Stefan Arndt, deputy chair Dr Sam Grover, and UWA senior lecturer Dr Caitlin Moore.

A week before the conference, UWA hosted a five-day flux data workshop supported by OzFlux and TERN. The workshop included lectures on eddy covariance theory and practice, hands-on training in processing raw data with the PyFluxPro tool, and an overview of the requirements for submitting flux tower data to the FLUXNET2025 global data collation effort. Industry partners LICOR Biosciences and Campbell Scientific also provided demonstrations of their instrumentation.

Dowerin Field Days

Crowds may have been lower than expected at the Dowerin GWN7 Machinery Field Days in 2024, but spirits were high as ever at the IOA stall.

The IOA Associate Director Professor Phil Vercoe, Professor Megan Ryan, Master's student Miranda Slaven and Communications Officer Guanhao Cheng manned the stall within the DPIRD shed.

The team were delighted to greet a mix of UWA graduates, current students and other visitors who were drawn in by the vibrant and engaging display.

The stall featured information on the UWA Farm Ridgefield's Best Practice Farming Systems (BPFS) Project, new pathways for prospective students to study agricultural science at UWA, Emerita Professor Lynette Abbott's SOILHEALTH app, the MLA and UWA BeefLinks partnership project and more.

Throughout the two-day event, visitors were especially interested in learning what research would be on show at the Shenton Park Field Station Open Day on 23 September.

The Hon Minister for Regional Development, Agriculture and Food and Hydrogen Industry Alannah MacTiernan MLC made an early appearance in the DPIRD shed.

Ms MacTiernan spoke with Honorary Research Fellow Dr Kevin Foster from DPIRD about his new ute guide for identifying harmful oestrogenic subterranean clovers in the field.

The guides, on display at the stall, proved very popular with farmers and researchers focused on sheep fertility.

Professor Megan Ryan and Professor Philip Vercoe at the IOA stall.

Mathieu Rousseau-Gueutin, Hackett Professor Kadambot Siddique, Tahira Rasheed, PhD candidates George Mercer and Agyeya Pratap, and Dr Fiona Dempster at the Institute info stall.

GRDC Grains Research Update

There was much to celebrate at GRDC 2024 Grains Research Updates in February.

Highly respected agricultural economist, UWA School of Agriculture and Environment Professor Ross Kingwell, was honoured with the Seed of Light Award for his outstanding contribution to Australia's grains industry.

Professor Kingwell, who is also chief economist with the Australian Export Grains Innovation Centre, presented at The UWA Institute of Agriculture's Industry Forum on 17 July, speaking to the theme 'Can agriculture reach Net Zero?'

Communications Officer Rosanna Candler and visiting researcher Tahira Rasheed were kept very busy discussing UWA-based agricultural research with visitors to the Institute's information stall.

The stall featured research posters from PhD candidate Manish Sharma and Master's student Angelia Tanu – who both presented at the 'Snapshots from new or early career researchers' on the second day.

Mike Carrol Travelling Fellowship

A captivated audience at the Mike Carroll Travelling Fellowship presentation evening were taken on a journey to the Scotland Highlands, over to Cambridge University, across the pond into France and through the streets of Melbourne.

To date, 30 UWA postgraduate students have benefitted from the Fellowship since the first recipient was awarded in 2003.

It was established as a memorial to former Director General of the WA Department of Agriculture, the late Dr Mike Carroll, in recognition of his commitment to agriculture.

In March, The UWA Institute of Agriculture held a special event for Carroll family and friends, during which four recent awardees delivered presentations on their Fellowship-sponsored travels.

Having now completed his PhD on identifying disease resistance genes in crops, Junrey Amas described his trip to France to learn from Dr Thierry Rouxel's lab.

Felipe Castro Urrea explained how he spent six weeks at the Highlander Lab in Scotland learning new techniques to assist his research into developing statistical models to analyse breeding data.

Manu Magar, whose research is focused on identifying heat responsive genes in wheat, participated in the 23rd International Congress of Genetics and Genomics Conference held in Melbourne.

In September, Manish Sharma attended an international conference at Cambridge in the UK, which has helped support his PhD to evaluate the potential of struvite as a sustainable phosphorus fertiliser source.

(Left to right) Junrey Amas, Manish Sharma, Hackett Professor Kadambot Siddique, Manu Magar, Felipe Castro Urrea, Marie-Louise Carroll, Helen Carroll and Coco Divola.

Best Practice Farming Systems Project: 2024 Highlights

The Best Practice Farming Systems (BPFS) Project at UWA Farm Ridgefield facilitates multidisciplinary research and innovation to deliver robust farming systems that are economically viable, environmentally credible and create tangible social benefits. The BPFS Project is guided by the following strategic priorities.

Mitigation of on-farm greenhouse gas emissions: Substantially reduce greenhouse gas emissions from ruminant livestock, cropping activities and promote widespread adoption of renewable energy in regional WA.

Adaptations for the changing climate: Implement climate adaptation innovations that protect the viability of livestock and cropping enterprises.

Profitable, ethical production systems: Profitable dryland farming systems that deliver clean, green and ethical products and outcomes that meet consumer and community expectations and underpin our social license.

Restoration of ecosystems and biodiversity: At landscape scale, use native plant species to restore biodiversity and soil functions to provide ecosystem services such as water availability, carbon capture and erosion prevention.

Education, community engagement and capacity building: Build partnerships with regional communities in targeted educational initiatives, capacity-building and outreach projects with triple bottom line outcomes and societal benefits.

Outreach

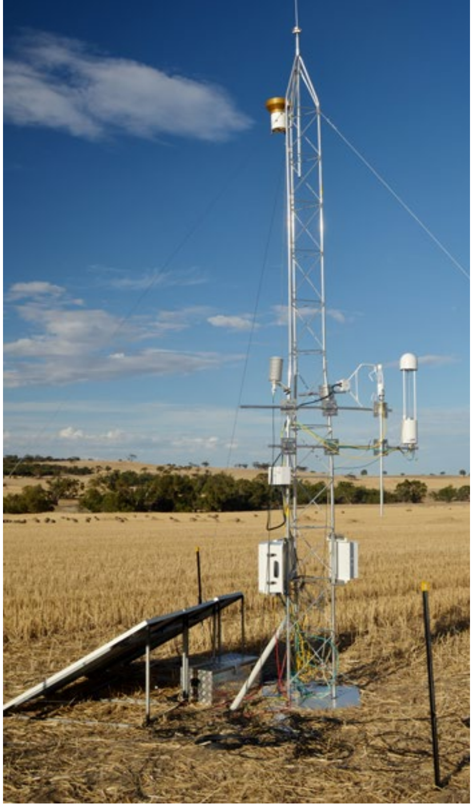
We engaged with farmers, the wider agricultural industry, scientific community and general public at several key events in 2024, including the GRDC Research Updates, Perth in February, the Soil Science Challenge Workshop, Pingelly in July, and the Dowerin Field Days in late August. At each event, we shared information about UWA Farm Ridgefield and the BPFS Project through flyers, posters, and conversations with attendees.

A highlight of the year was the visit by Dr Ismahane Elouafi, Executive Managing Director of the CGIAR as part of her official visit to UWA. Accompanied by Professor Kadambot Siddique, Professor Wallace Cowling, and Business Manager Diana Boykett, Dr Elouafi toured several key research sites across the farm, including the Methane Emissions Reduction in Livestock (MERiL) project. There, she engaged with researchers Dr Suyog Subedi and Angad Singh to learn about UWA's contributions to reducing livestock emissions. CGIAR has a number of research farms similar to Ridgefield and the knowledge sharing was hugely beneficial.

Another highlight was the visit of the Governor of Western Australia, the Honourable Chris Dawson APM, and his wife, Mrs Darrilyn Dawson, to UWA Farm Ridgefield in October. With longstanding ties to regional communities and a strong personal interest in agriculture, the Governor and Mrs Dawson engaged with the research activities underway at the farm. Hosted by IOA, the visit included a guided tour of the farm's research infrastructure and trial plots, where they discussed current innovations in crop and livestock management. The visit also served as a platform for dialogue on how collaboration between government, academia, and industry can drive agricultural advancement and support rural communities in Western Australia.

In late November, UWA Farm Ridgefield welcomed participants of the annual OzFlux Conference for a field visit to its flux tower and the Avon Critical Zone Observatory, despite heavy rain and muddy conditions. The visit, part of a broader event hosted by UWA's Centre for Water and Spatial Science with support from TERN, highlighted UWA Farm Ridgefield's role in the national and global flux monitoring network. Attendees explored research on carbon, water, and energy exchanges across ecosystems, and learned about UWA's paired flux tower sites, including the TERN Boyagin Wandoo Woodland.

The BPFS Project is part of the national The Animal Welfare Collaborative, Australian Association of Animal Science, and Pingelly Community Resource Centre. It is a member of the Worldwide Universities Network's Global Farm Platform (which includes 23 Institute members and 15 farm platforms


across all continents), the Critical Zone Exploration Network, and the Terrestrial Ecosystems Research Network.

In 2024, the BPFS Project's strong online presence enabled engagement with people all around the world. A total of over 2,600 people were following the BPFS Project page on Facebook by the end of the year.

Throughout 2024, seven newsletter articles, thirteen peer-reviewed research papers and 1 book chapter relating to research, extension and adoption activities on Ridgefield were published. This includes a paper published in the prestigious journal Nature Communications.

Research, Education and Training

On-farm education is integral to the BPFS Project, from high school students through to Bachelor, Master's and Doctorate level. The project being based at UWA Farm Ridgefield which operates as a commercial enterprise provides an excellent platform for practical field experience.

The Massive Open Online Course Discover Best Practice Farming for a Sustainable 2050 attracted a further 4000 enrolments in 2024, reaching a total of more than 44,000 since it was launched in 2017. This free course provides an overview of major issues in sustainable agriculture and illustrates them with the four key enterprises of the BPFS Project: livestock, cropping, sustainability and a vibrant community.

Throughout the year, more than 70 UWA students attended study excursions to Ridgefield or visited for research purposes. Forty students from the AGRI2201 Pasture and Livestock Systems unit, about five students from the SCIE5507 Food Fibre and Fuel Security unit, and 30 students as part of the ANIM3306 Clean Green and Ethical Animal Production unit.

UWA Master's student Callum Connolly completed research at UWA Farm Ridgefield on the effects of exogenous melatonin on ram sperm quality under heat stress conditions. Leah Daymond, also a UWA Master's student, conducted a study at the farm examining the potential application of Planet micro-satellite data for weed patch detection in Western Australian cropping fields.

Three international PhD students worked at UWA Farm Ridgefield in 20243; Manish Sharma, Linda Lindongi and Richard Ang. Five postgraduate students utilised Ridgefield for their research projects, including:

- Jessie Weller (UWA): Critical Zone architecture influences water storage, fate and transport within a deeply weathered lateritic landscape in Western Australia's wheatbelt
- Callum Connolly (Curtin University): Exogenous melatonin and ram sperm quality during heat stress project
- Leah Daymond: Potential to utilise Planet micro-satellite data for weed patch detection in WA cropping fields.
- Samantha Harvie: Exploring protein storage efficiency during wheat grain development
- Elina Rittelmann-Woods: Plant diversity, soil microbes and soil carbon storage in ecological restoration.

Several important partnerships through the BPFS Project at UWA Farm Ridgefield were formed or nurtured during 2024. CSIRO, led by Dr Hayley Norman, continued work on the implementation of the Edible Shelter project. Murdoch University maintained two key projects: Managing Merino weaners to survive and thrive and The impact of crop height on survival of twin-born lambs. MLA supported research on heat stress in livestock, and the GRDC supported a project on predicting nitrogen cycling and losses in Australian cropping systems, with enhanced modelling through augmented measurements.

UWA Farm Ridgefield continued to attract international and national visitors in 2024, reflecting its role as a hub for collaborative agricultural research and innovation. On 24 March, Professor Jim Kinsella from the Faculty of Agriculture at University College Dublin (Ireland) visited the farm with Emeritus Professor Graeme Martin. On 10 May, Ms Cassandra Yip from Wavemaker Impact, a Singapore-based climate-tech venture capital firm, toured the site. In July, a group from École d'Ingénieurs de PURPAN (France), Ms Lucie Jouve, Mr Guilhem Rivet, Ms Julie Vautier, and Mr Mathis Calvel, also visited. Later in the year, on 28 November, Professor Mike Liddell from James Cook University visited to inspect the OzFlux tower and Avon Critical Zone Observatory site, guided by Dr Caitlin Moore.

Photos (From left):

Professor Kadambot Siddique, Dr Ismahane Elouafi, and Associate Director Professor Wallace Cowling in front of canola.

UWA Master's student Allan Williams runs a demonstration.

Avon River CZO at UWA Farm Ridgefield.

The Governor of WA Chris Dawson pictured second from right at UWA Farm Ridgefield.

Media releases 2024

Date	Title
9 January	Diversified crop rotations improve soil health, environmental impact, and yield
17 January	Winged bean research takes flight after 50 years
2 February	Passionate students awarded prestigious scholarships
27 February	Agricultural expert honoured for work in grain industry
13 March	Improving risk-reward outcomes for Australian grain growers
15 March	Groundwater refill waning as WA's climate dries
20 March	Dung dynasty – the plant boosting powers of beetle recyclers
26 March	Biochar research pioneer honoured with national award
3 April	Centenary of salinity research marked by award relaunch
9 April	Funding gives plants in space a growth boost
1 May	Inaugural joint PhD candidate making international bonds
9 May	Study explores what helps agritourism grow
15 May	UWA Research on the Record: Meet Dr Bhagya Dissanayake
22 May	Helping growers see natural capital as an asset class
23 May	Wild species provide insights into improving chickpea crop
25 June	Inaugural John Cripps scholar bites into big apple project
29 July	Unearthing innovative potting mix from waste products
29 July	UWA PhD candidates scoop agriculture scholarships
30 July	Scientific excellence recognised in award nominations
27 August	The UWA Institute of Agriculture releases Annual Research Report 2023
21 October	Annual legume breeding Australia releases first two clover varieties
22 October	Food for thought - tool measures dietary plastic exposure
31 October	Vale Emeritus Professor Alan Robson
20 November	UWA celebrates 10 Highly Cited researchers in 2024
29 November	UWA named country's best for soil sciences, nine researchers top list
6 December	Call for two-fold approach to create sustainable food supplies
9 December	Cultivating a legacy with 50 years of soil science at UWA

Awards and industry recognition

Name	Award
H/Prof Kadambot Siddique	Adjunct Professor in Plant Physiology – ICAR-Indian Agricultural Research Institute
E/Prof Hans Lambers	Life Member of the Australian Society of Plant Scientists
Peter Panizza	Westpac Future Leaders Scholarship
Professor Eric Yirenkyi Danquah	100 Most Reputable Africans – 2024 list
Professor Ross Kingwell	Grains Research and Development Corporation 2024 Seed of Light Award
Dr Zakaria Solaiman	2024 Australia New Zealand Biochar Industry Group (ANZBIG) Forum Best Research Award
Professor Jacqueline Batley	Finalist for WA Scientist of the Year – 2024 Premier's Science Awards
Adjunct Professor Jairo Palta	Fellow of the Crop Science Society of America
Dr Kelsey Pool	Finalist for 2024 WA Young Tall Poppy Award
Golam Azam	John Cripps Horticulture Scholarship
Adjunct Professor Susana Neto	International Eminent Scientist Award – World Congress 2023 (Water, Agriculture and Climate), India
Darcy Lefroy	Postgraduate scholarship – WA Agricultural Research Collaboration
Chloe Rout	Postgraduate scholarship – WA Agricultural Research Collaboration
Montana Walsh Baddeley	Postgraduate scholarship – WA Agricultural Research Collaboration
Roberto Lujan Rocha	Postgraduate scholarship – WA Agricultural Research Collaboration
Yusi Zhang	Postgraduate scholarship – WA Agricultural Research Collaboration
Mahnaz Afsar	Postgraduate scholarship – WA Agricultural Research Collaboration
Saira Azmat	Postgraduate scholarship – WA Agricultural Research Collaboration
Huyen Pham	Postgraduate scholarship – WA Agricultural Research Collaboration
Angelia Tanu	Postgraduate scholarship – WA Agricultural Research Collaboration
Emerita Professor Lynette Abbott	2024 UWA Chancellors Award
H/Professor Kadambot Siddique	Adjunct Professor in the Centre for Environment and Sustainable Development, Jamia Hamdard University
H/Professor Kadambot Siddique	Visiting Professorship at Northwest Agriculture and Forestry University China
H/Professor Kadambot Siddique	Visiting Professorship at Universitas Brawijaya, Indonesia
H/Professor Kadambot Siddique	Adjunct Professorship at Jamia Hamdard, India
Professor Phil Vercoe	Fellow of the Australian Association of Animal Sciences
Professor Ken Flower	Fellow of the Australian Society of Agronomy
H/Professor Kadambot Siddique	Adjunct Professorship at China Agricultural University, China
H/Professor Kadambot Siddique	Distinguished Professorship at Shenyang Agricultural University, China
UWA Students of Natural and Agricultural Sciences (SNAGS)	First place in the Ag Institute Australia WA Industry All Stars competition
Agricultural Sciences at The University of Western Australia	Ninth in the world and number one in Australia – Shanghai Academic Ranking of World Universities 2024
H/Professor Kadambot Siddique	The Australian's 2025 Research Magazine – Leading researcher in the field of Agronomy & Crop Science
Professor Sergey Shabala	The Australian's 2025 Research Magazine – Leading researcher in the field of Botany
Professor Nanthi Bolan	The Australian's 2025 Research Magazine – Leading researcher in the field of Environmental Sciences
Professor Martin Barbetti	The Australian's 2025 Research Magazine – Leading researcher in the field of Plant Pathology
Soil Sciences at The University of Western Australia	The Australian's 2025 Research Magazine – Leading research institution in the field
Professor Sergey Shabala	Senior Research Award – 2024 Vice-Chancellor's Research Awards
Emerita Professor Lynette Abbott	Chancellor Award
H/Professor Kadambot Siddique	Recognised as 2024 Top Cited Scholar by Scilit

New postgraduate research students

Name	Topic	School	Supervisor(s)	Funding body
Putri Setyowati	Rice Farmers' Resilience to Climate Change in Indonesia: Insights from a Social-Ecological Approach	UWA School of Agriculture and Environment	Dr Ram Pandit Assoc/Prof Fay Rola-Rubzen	CEFS, Ministry of Ed, Culture, Research and Tech, Indonesia
Oanh Nguyen	Technological Innovation in the Australian Wine Industry: A Study of CRM Platform and AR Labelling Adoption in SME Wineries	UWA School of Agriculture and Environment	Prof Michael Burton Dr James Fogarty Dr Amin Mugera	RTP Fees Offset - International Student Research Training Program Stipend - International Student
Pragya Poudel	Molecular and physiology aspects of tropical grapevines	School of Molecular Sciences	Assoc/Prof Michael Considine H/Prof Kadambot Siddique	Scholarship for International Research Fees UWA – CSC and Innovating the Growth of Tropical Table Grapes HDR Scholarship
Darcy Lefroy	Human factors influencing the adoption and diffusion of novel biotechnology	UWA School of Agriculture and Environment	Prof David Pannell Dr Vanessa Bowden Dr Aditi Mankad	Commonwealth Research training stipend and OPEX funding from the CSIRO Immune Resilience Future Science Platform
Mostarak Munshi	Thesis title not yet confirmed	UWA School of Agriculture and Environment	Dr Zakaria Solaiman H/Prof Kadambot Siddique	RTP Stipend - International Student UWA International Fee Scholarship
Ruwani Hapuarachchige	Thesis title not yet confirmed	UWA School of Agriculture and Environment	Prof Nanthi Bolan H/Prof Kadambot Siddique Dr Zakaria Solaiman	ARC Linkage Higher Degree by Research Scholarship Scholarship for International Research Fees
Md Golam Azam	Characterising Cripps Pink apple and its mutants using advanced genetic and genomic tools	UWA School of Agriculture and Environment	H/Prof Kadambot Siddique Assoc/Prof Michael Considine Dr Sultan Mia Dr Zakaria Solaiman	RTP Stipend - International Student UWA International Fee Scholarship
Kamrun Nahar Sheuly	Thesis title not yet confirmed	UWA School of Agriculture and Environment	H/Prof Kadambot Siddique Dr Zakaria Solaiman	RTP Stipend - International Student UWA International Fee Scholarship
Boyu Zheng	Thesis title not yet confirmed	School of Biological Sciences	E/Prof Hans Lambers Dr Jiayin Pang H/Prof Kadambot Siddique	Scholarship for International Research Fees China and UWA - CSC HDR Top-Up Scholarship
Shuyan Li	Thesis title not yet confirmed	School of Biological Sciences	H/Prof Kadambot Siddique E/Prof Hans Lambers Dr Jiayin Pang	Scholarship for International Research Fees China and UWA - CSC HDR Top-Up Scholarship
Saira Azmat	Effect of phosphorus availability and root morphological traits on adaptive responses to salinity stress in barley (Hordeum vulgare)	UWA School of Agriculture and Environment	Dr Yinglong Chen Assoc/Prof Sergey Shabala Dr Zakaria Solaiman	HDR Scholarship & Scholarship for International Research Fees
Mahnaz Afsar	Developing demand-driven extension strategies to improve adoption of precision agriculture technologies in South-West Western Australia	UWA School of Agriculture and Environment	Assoc/Prof Marit Kragt Prof Steven Schilizzi Dr Joanne Wisdom	ARC TC for Behavioural Insights for Technology Adoption & Scholarship for International Research Fees

Name	Topic	School	Supervisor(s)	Funding body
Eshrat Mahfuza	Interlinkage between market demand for improved agricultural products and adoption of modern farming technologies in climate-prone developing economies	UWA School of Agriculture and Environment	Assoc/Prof Fay Rola-Rubzen Assoc/Prof Amin Mugera Assoc/Prof Atakelty Hailu	Research Training Program Stipend - International Student & UWA International Fee Scholarship
Yusi Zhang	Assessing and enhancing pasture and rangeland resilience in Western Australia: Integrative approaches for productivity mapping and climate impact analysis	School of Civil, Environmental and Mining Engineering	Assoc/Prof Nik Callow Dr Qiaoyun Xie	RTP Stipend - International Student WAARC HDR Top-Up Scholarship and UWA International Fee Scholarship
Angelia Tanu	Enhancing field establishment potential for the next generation of climate-resilient canola	School of Biological Sciences	Prof Erik Veneklaas Dr Matthew Nelson Prof Wallace Cowling Dr Virginia Mwape Dr Sarah Rich	WAARC HDR Top-Up Scholarship and University Postgraduate Award
Chloe Rout	Evaluating the benefits and overcoming barriers to adoption of intercropping and companion cropping of canola or cereals with legumes	UWA School of Agriculture and Environment	Professor Ken Flower Dr Andrew Fletcher Dr Mike Ashworth	WAARC HDR Top-Up Scholarship and RTP Stipend - Domestic Student
Montana Walsh Baddeley	Understanding the genetic factors influencing meat quality and performance of rangelands beef cattle throughout the WA supply chain	UWA School of Agriculture and Environment	Professor Phil Vercoe Assoc/Professor Dominique Blache Dr Matt Walcott Dr Fiona Dempster	WAARC HDR Top-Up Scholarship and RTP Stipend - Domestic Student
Mithun Ghosh	Integrating Renewable Energy Technologies into Australian Farming Systems: Exploring economic viability and community concerns	UWA School of Agriculture and Environment	Professor Marit Kragt Dr Germán Puga	ARC TC for Behavioural Insights for Technology Adoption

Memoranda of Understanding

Name	Date
Udayana University	January 2024
Lanzhou University	March 2024
Tamil Nadu Agricultural University	March 2024
Universitas Brawijawa	July 2024
UWA and Northwest Agriculture & Forestry University	September 2024
UWA and China Agricultural University	October 2024
UWA and Beijing University of Agriculture	November 2024

New research grants

Title	Funding period	Funding body	Investigators
UWA MERiL3-2	2024 - 2027	Department of Industry, Science and Resources	Stephanie Payne, Suyog Subedi, Dr Joy Vadhanabhuti, Dr Zoey Durmic
GGA Student Bursary	2024 - 2026	Grower Group Alliance	Prof Kadambot Siddique, Huyen Pham
Food hypersensitivity in Australia and NZ	2024 - 2025	Food Standards Australia and New Zealand	A/Prof Michael Burton, Adj/Prof Dan Rigby
Pasture diversification to promote climate resilience	2024 - 2028	Department of Agriculture, Fisheries and Forestry	Dr Sasha Jenkins, Prof Kadambot Siddique, Dr Bede Mickan, E/Prof Lyn Abbott, Prof Nanthi Bolan, A/Prof Zakaria Solaiman, Tammie Harold, Prof Matthias Leopold.
Grain Automate Program 1: Developing capability, awareness, and preparedness for autonomy in the tertiary education sector	2024 - 2027	GRDC	Dr Andrew Guzzomi, Dr Wesley Moss, Prof Marit Kragt, A/Prof James Fogarty, Prof Gustavo Alckmin, E/Prof Graeme Martin, Karen Eyles, Alysia Kepert
Australian Plant Phenomics Network (APPN) - Strategic Initiative Fund	2024 - 2025	Department of Education	Dr Nic Taylor
Exploring Antimicrobial Resistance in Conventional and Biological Farming Systems	2024 - 2028	SAAFE CRC	Mostarak Munshi, A/Prof Zakaria Solaiman, Prof Kadambot Siddique, Prof Zed Rengel, Paul Storer
CRC Zero Net Emissions in Agriculture	2024 - 2033	Department of Industry, Science and Resources	Prof Phil Vercoe, Prof Marit Kragt, Dr Heather Bray, A/Prof James Fogarty, Dr Caitlin Moore
Building resilient organic weed management systems with precision smart sprayer technologies	2024 - 2026	Department of Agriculture (US)	Dr Wesley Moss, Dr Andrew Guzzomi
Herbicide resistance status of grain and cotton cropping regions - strategic insights for RDE	2024 - 2028	GRDC	Dr Mechelle Owens
ARC Training Centre in Predictive Breeding for Agricultural Futures	2024 - 2029	ARC	Prof Dave Edwards, Dr Michael Considine, Dr Nic Taylor, Prof Harvey Millar, Prof Jacqueline Batley
Remote operations for unscrewed spaceflight control of plant growth	2024	Space Research SUPPORT Scheme (International Space Centre)	Prof Harvey Millar, Dr James Lloyd
MLA DC: Business case development – improving the north-west cattle herd	2024 - 2025	Meat & Livestock Australia	Dr Kelly Pearce

Title	Funding period	Funding body	Investigators
CRC SAAFE Foundation Fellow Project – Agricultural systems solutions	2024 – 2027	CRC SAAFE	Dr Zakaria Solaiman, Prof Kadambot Siddique
GRDC International Visiting Fellowships Programs (IVFP) 2023/24	2024	GRDC	Dr Sheng Chen, Prof Wallace Cowling, Prof Kadambot Siddique
Mapping dung beetle activity & economic benefits across Australia	2024 – 2026	Meat & Livestock Australia	Prof Theo Evans
Development of new genetic sources for canola heat tolerance	2024 – 2028	GRDC	Dr Sheng Chen, Prof Wallace Cowling, Prof Kadambot Siddique
Pastures 365: Can more diverse pastures build resilience to support 365 days of feed productions	2024 – 2028	DAFF	Prof Phil Vercoe
Quantifying greenhouse gas emissions from the decomposition of crop residues	2024 – 2027	GRDC	Dr Louise Barton
Barriers and opportunities for Natural Asset Companies in Western Australia's agricultural sector	2024 – 2025	Grower Group Alliance	Dr Ana Manero, Ram Pandit, Dr Fiona Dempster, Prof Marit Kragt, Thomas Picton-Warlow, Lizzy Lowe
Control of plant-fungal symbiosis by new plant hormones	2024 – 2027	Australian Research Council	Mark Waters, Prof Megan Ryan, Philip Brewer, Caroline Gutjahr
Test bed for fugitive methane emissions sensors	2024	Future Energy Exports CRC	Bruce Norris, Kwanghee Jeong
Development of "climate-smart" plants with improved nutrient acquisition	2024	UWA	James Lloyd, Ryan Lister
Livecorp -Interpreting Animal Welfare	2024 – 2025	Australian Livestock Export Corporation Ltd	Shane Maloney, Dominique Blache, Luoyang Ding, David Walker, Alan Tilbrook, John Gaughan, Angela Lees, Mark Hutchinson, Rohan Walker
ARC Centre of Excellence in Plants for Space	2024 -2030	Australian Research Council	Prof Ian Small, Prof Harvey Millar, Prof Ryan Lister
Effective virus management in grain crops	2024-2029	GRDC	Adjunct Prof Roger Jones

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Farmer

Dr Dawson Bradford
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Farmer

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2024 Publications

Peer Reviewed Journals

1. Abbasi AA, Saha S, Begum IA, Rola-Rubzen MF, McKenzie AM, Alam MJ (2024). Does rural transformation affect rural income inequality? Insights from cross-district panel data analysis in Bangladesh. *Heliyon* **10(9)** doi: 10.1016/j.heliyon.2024.e30562
2. Adhikari SP, Timsina KP, Rola-Rubzen MF, Timsina J, Brown PB, Ghimire YN, and Thapa Magar DB (2024). Determinants of conservation agriculture-based sustainable intensification technology adoption in smallholder farming systems: Empirical evidence from Nepal. *Journal of Agriculture and Environment for International Development (JAEID)* **118** (1) 31–50
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4. Amadou I, Houben D, Lambers H, and Faucon MP (2024). Key role of root trait combinations and plasticity in response to phosphorus forms on phosphorus-acquisition in agroecosystems. *Plant & Soil* doi: 10.1007/s11104-024-06848-8
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11. Batt PJ (2024). Food security: planning for our collective future. Proceedings 2nd Intl Conference on Food Technology and Nutrition, Bali. *Bio Web of Conferences* **98** 05002 doi: 10.1051/bioconf/20249805002
12. Bezerra ACM, Kotula L, Ortiz-Silva B, Medici LO, Colmer TD, and Reinert F (2024). NaCl-induced effects on photosynthesis, ion relations, and growth of *Chloris gayana Kunth* in the presence of two levels of KCl. *Plant Physiology and Biochemistry* **216** doi: 10.1016/j.plaphy.2024.109136
13. Bolan N, Srinivasarao C, Rocco C, Bolan S, Wani SA, Ahmad P, Weiss D, Northover G, Sánchez-Palacios JT, Cheng M, Bell R, Kumar GR, Naidu GM, Hou D, Jia X, Xie Y, Wang H, Antoniadis V, Melo TM, Shaheen SM, Rinklebe J, Kirkham MB, and Siddique KHM (2024). Zinc in soil-crop-animal-human health continuum. *Advances in Agronomy* doi: 10.1016/bs.agron.2024.09.004
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36. Ding Y, Gao X, Shu D, Siddique KHM, Song X, Wu P, Li C, Zhao X (2025). Enhancing soil health and nutrient cycling through soil amendments: Improving the synergy of bacteria and fungi. *Science of The Total Environment* **923** doi: 10.1016/j.scitotenv.2024.171332
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38. Dolatabadian A, Neik TX, Danilevicz MF, Upadhyaya SR, Batley J, and Edwards D (2024). Image-based crop disease detection using machine learning. *Plant Pathology* doi: 10.1111/ppa.14006
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43. Farooq M, Rafique S, Zahra N, Rehman A, and Siddique KHM (2024). Root system architecture and salt stress responses in cereal crops. *Journal of Agronomy and Crop Science* **210** doi: 10.1111/jac.12776
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49. George TS, Chen Y, and Oliveira MT (2024). Editorial: Belowground adaptation of plants to climate change. *Plant & Soil* doi: 10.1007/s11104-024-06560-7
50. Gholamhoseini M, and Dolatabadian A (2024). Sesame renaissance: Iran's emerging influence in the global sesame market. *OCL - Oilseeds and Fats, Crops and Lipids* **31** doi: 10.1051/ocl/2024024
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55. Gu Y, Xu Q, Zhou W, Han C, and Siddique KHM (2024). Enhancing Faba Bean Yields in Alpine Agricultural Regions: The Impact of Plastic Film Mulching and Phosphorus Fertilization on Soil Dynamics. *Agronomy* **14**(3) 447 doi: 10.3390/agronomy14030447
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65. Han C, Zhou W, Gu Y, Wang J, Zhou Y, Shi Y, and Siddique KHM (2024). Effects of tillage regime on soil aggregate-associated carbon, enzyme activity, and microbial community structure in a semiarid agroecosystem. *Plant & Soil* doi: 10.1007/s11104-023-06453-1
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Acronyms

AAGI	Analytics for the Australian Grains Industry
AAS	Australian Award Scholarship
ACCU	Australian Carbon Credit Units
ACIAR	Australian Centre for International Agricultural Research
ACT	Australian Capital Territory
ADISER	Australian Department of Industry, Science, Energy and Resources
AEGIC	Australian Export Grains Innovation Centre
AGT	Australian Grain Technologies
AI	Aerated irrigation
Al	Aluminum
ALBA	Annual Legume Breeding Australia
AM	Arbuscular mycorrhizal
AMR	Antimicrobial resistance
AMS	Agricultural mechanization services
ANABP	Australian National Apple Breeding Program
APRI	Australasian Pork Research Institute
APSIM	The Agricultural Production Systems Simulator
APVMA	Australian Pesticides and Veterinary Medicines Authority
ARARI	Amhara Regional Research Institute
ARB	Antibiotic-resistant bacteria
ARC	Australian Research Council
ARG	Antibiotic resistance gene
AWB	Australian Wheat Board
AWI	Australian Wool Innovation
BAR	Biochar application rates
BCCM	Business Council of Co-operatives and Mutuals
BGS	Brunei Government Scholarship
BHP	Broken Hill Proprietary (company)
BITA	ARC Training Centre for Behavioural Insights for Technology Adoption
BM	Black film
BPFS	Best Practice Farming Systems
C	Carbon
Ca	Calcium
CAAS	Chinese Academy of Agricultural Sciences
CAS	Chinese Academy of Sciences
CASI	Conservation agriculture-based sustainable intensification
CBH	Co-operative Bulk Handling (company)
Cd	Soil cadmium
CDI	Cotyledon Disease Index
CEI:AgER	The Centre for Engineering Innovation: Agriculture & Ecological Restoration
CER	Carbon efficiency ratio
CERU	Co-operative Enterprise Research Unit
CGIAR	Consultative Group on International Agricultural Research
CGIAR	Consultative Group on International Agricultural Research
CitWA	Citizen of Western Australia
CLG	Clay, lime, gypsum
CME	Co-operative and Mutual Enterprise
CoE	Centre of Excellence
COGGO	Council of Grain Growers Organisation
CPEC	China-Pakistan Economic Corridor
CRC	Cooperative Research in Australia
CRC - SAAFE	Cooperative Research in Australia for Solving Antimicrobial Resistance in Agribusiness Food and Evironment.
CRCNA	The Cooperative Research Centre for Developing Northern Australia
CRISPR	Clustered regularly interspaced short palindromic repeats
CRNFs	Controlled-release nitrogen fertilisers
CRY	Cryptochromes
CS	Climate-Smart
CSAP	Climate-Smart Agricultural Practices
CSC	Chinese Scholarship Council
CSIC	Comisión Sectorial de Investigación Científica
CSIRO	Commonwealth Scientific and Industrial Research Organization
Cu	Cooper
CZO	Critical Zone Observatory
DAFF	Department of Agriculture, Fisheries and Forestry
DCSP	Dairy climate-smart practices
DEP	Differentially expressed proteins
DHL	Doubled Haploid
DISER	Department of Industry, Science and Resources
DOST-SEI	Department of Science and Technology - Science Education Institute. Republic of Philippines.
DPIRD	Department of Primary Industries and Regional Development, Western Australia
DWDH	Doubled-haploid
EFd	Emission factors
FA	Formic Acid
FBG	Faba bean gall
Fe	Iron
FISP	Farmer Input Support Program
FMS	Fertiliser mechanization services
FWEC	Faecal worm egg count
GABA	Gamma-Aminobutyric Acid
GBMDI	Gradient Boosting Method Drought Index
GC-MS	Gas Chromatography-Mass Spectrometry
GDDs	Growing degree days
GGA	Grower Group Aliance
GHG	Greenhouse gas
GIS	Geographic Information System
GoB	Green-on-brown
GoG	Green-on-green
GPC	Grain Protein Content
GPS	Global Positioning System
GRDC	Grains Research and Development Corporation
GWAS	Genome-wide association studies
GWI	Groundwater irrigation
GY	Grain Yield
HID	Hetao Irrigation District
HPA	Hop Products Australia
HPTLC	High-performance thin-layer chromatography
HR	Hypersensitive response
ICARDA	Australian Center for International Agricultural Research and the International Center for Agricultural Research in the Dry Areas
IMF	Improving intramuscular fat
IOA	The UWA Institute of Agriculture
IP	Inflorescence primordia
IPM	Integrated pest management
ITM	Inorganic trace minerals
IWP	Irrigation water productivity
K	Potassium
KASP	Kompetitive allele specific
LAI	Leaf area index
LRR	Leucine-rich repeat
LULC	Land use and land cover
LysM	Lysin Motif
MAS	Marker-assisted selection
MB	Biochar
MENR	Models to predict nutrient requirements
MERiL	Methane Emissions Reduction in Livestock Program
Mg	Magnesio
MLA	Meat and Livestock Australia
MN	Film mulching alone
Mn	Manganese
MOOC	Massive Open Online Course
MP	Microplastics
MS	Film mulching with straw
N	Nitrogen
NAC	Neutral Ammonium Citrate

NB	Biochar incorporation
NCP	North China Plain
NFB	Nitrogen-fixing bacteria
NIL	Near-isogenic lines
NN	Flat planting without mulching
NNSFC	National Natural Science Foundation of China
NPK	Nitrogen, phosphorus, and potassium
NPZ	Norddeutsche Pflanzenzucht
NRE	Nitrogen recovery efficiency
NRM	Natural Resource Management
NS	Flat planting with straw
NSMP	National Sheep Methane Program
NSPEI	Standardized Precipitation Evapotranspiration Index
NSW	New South Wales
NSW DPI	New South Wales Department of Primary Industries
NUE	Nitrogen Use Efficiency
OTM	Organic trace minerals
OTU	Operational taxonomic units
P	Phosphorus
PABRA	Pan Africa Bean Research Alliance
PCR	Polymerase Chain Reaction
PFPN	Partial factor productivity of nitrogen
PGR	Polygenic resistance
pH	Potential of hydrogen
PHOTs	Phototropins
PHY	Photoreceptors include phytochromes
PIRSA	Department of Primary Industries and Regions
PM	Plastic film mulching
PRE	Phosphorus resorption efficiency
pRLD	Planar root length density
PSB	Phosphate-solubilizing bacteria
Pty Ltd	Proprietary Limited
PUE	Productivity per unit P uptake
PUE	P-use efficiency
PVC	Polyvinyl chloride
PVC	Polyvinyl chloride
QLD	Queensland
QR	Quantitative resistance
qRT-PCR	Quantitative real-time reverse-transcription polymerase chain reaction
QTL	Quantitative Trait Loci
R&D	Research and Development
RCBP	Rapid Cooking Bean Project
RGA	Resistance gene analogs
RLK	Receptor-Like Kinases
RLP	Receptor-like proteins
RR	Roundup Ready®
SARDI	South Australian Research and Development Institute
SCF	Subcutaneous
SGR	Single-gene dominant resistance
SI	Symptom intensity
SNAGS	UWA's Students of Natural and Agricultural Sciences
SNP	Single Nucleotide Polymorphism
SOCS	soil organic carbon storage
SRFSI	Sustainable and Resilient Farming Systems Intensification
SR-I	straw incorporation
SR-M	Straw mulching
SSWM	Site-specific weed management
STR	Struvite
SW WA Hub	Grower Group Alliance- Southwest WA Drought Resilience Adoption and Innovation Hub
SWI	Surface water irrigation
TERN	Terrestrial Ecosystem Research Network
TF	Transparent film
TGW	Targeted Genotyping with Whole-genome arrays
TILLING	Targeting Induced Local Lesions in Genomes
TM	Transparent film mulching
TM-CC	Transmembrane-coiled-coil
TS	Traceability systems
TSP	Triple Superphosphate
TSSIR	Temperature-sensitive invasion resistance
TuMV	Turnip Mosaic Virus
UAV	Unmanned aerial vehicle
UDELAR	Universidad de la República Oriental del Uruguay
UK	United Kingdom
UNE	University of New England
UPE	Uptake efficiency
USAID	United States Agency for International Development
UTE	Utilization efficiency
UWA	The University of Western Australia
VC	Virus concentration
VF	Visceral Fat
VFA	Volatile fatty acids
VIN	Vaculoar invertase
WA	Western Australia
WAARC	WA Agricultural Research Collaboration
WALRC	Western Australian Livestock Research Council
WAMMCO	The Western Australian Meat Marketing Co-operative
WP	Water productivity
WUE	Water use efficiency
Zn	Zink
ZNE	Zero Net Emissions

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