



THE UNIVERSITY OF
**WESTERN
AUSTRALIA**

Institute of
Agriculture

Annual Research Report 2025

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.



Pictured (left to right) UWA Work Health and Safety Advisor Asli Ceylan, UWA Core Research Infrastructure Director Greg Cozens, Professor Kadambot Siddique and Farm Manager Tim Watts at UWA Farm Ridgefield.
Credit: Diana Boykett

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Director's overview



It is my great pleasure to present the 2025 Annual Research Report of The University of Western Australia's Institute of Agriculture (IOA).

This year has been one of remarkable achievement, deep collaboration, and renewed ambition as we work together to shape the future of agriculture in Australia and around the world.

Our research community continued to excel, publishing more than 300 journal articles, books, and book chapters, and welcoming a dynamic new cohort of PhD students. Many of our academics were recognised with prestigious national and international awards. These accomplishments helped UWA achieve a remarkable ranking: first in Australia and 13th globally in Agricultural Sciences in the [2025 Academic Ranking of World Universities](#). This honour reflects the strength and vision of our six Research Themes, which drive innovation in sustainable farming, food security, and agricultural engineering.

Throughout 2025, The UWA Institute of Agriculture served as a vital bridge between research, industry, and government. Our 19th Annual Industry Forum, attended by more than 180 participants, invited us to imagine the next two decades of agricultural research, development, and extension. Professor Fiona Wood AO delivered an inspiring overview address, complemented by the insights of Dr Beth Woods, sparking thoughtful and constructive dialogue among farmers, researchers, and industry leaders.

Innovation was also at the heart of the 31st Hector and Andrew Stewart Memorial Lecture, where University of Sydney Professor Salah Sukkarieh illuminated the transformative power of robotics, AI, digital twins, and IoT in modern agriculture. His message was clear: the future of farming is both physical and digital, and the opportunities ahead are extraordinary.

Agriculture featured prominently at the 2025 Winthrop Society High Tea in November, where we celebrated the profound impact of philanthropy on research and

education. IOA's contributions to climate resilient cropping, sustainable farming systems, and global food security were highlighted as examples of research that not only advances knowledge but also strengthens communities and safeguards our shared future.

Our partnerships continued to flourish. UWA secured \$17.7 million in new research funding in agriculture and related areas, and our externally funded portfolio remained strong, including our ongoing involvement in the Cooperative Research Centre for Solving Antimicrobial Resistance in Agribusiness, Food and Environments (CRC SAAFE) and Cooperative Research Centre for Zero Net Emissions from Agriculture (CRC ZNE-Ag) initiatives. These collaborations reflect the trust placed in UWA to lead research that is innovative, impactful, and globally relevant.

I extend my heartfelt thanks to our staff, researchers, associates, students, board members, research theme leaders, and our national and international collaborators and funding partners. Your dedication, creativity, and commitment continue to elevate The UWA Institute of Agriculture as a global leader in agricultural research and education.

Professor Kadambot Siddique

AM, CitWA, FTSE
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 2025, the Industry Advisory Board (IAB) continued to be a vital pillar in The UWA Institute of Agriculture's (IOA) mission to foster a resilient and sustainable future for agriculture in Western Australia and beyond.

Comprising dedicated, forward-thinking farmers and influential leaders from across the agricultural sector, the Board has offered invaluable guidance and strategic insight. Their expertise has not only strengthened the IOA's connections with industry but also positioned the Institute to lead on tackling global agricultural challenges. Thanks to their ongoing support, the IAB has been instrumental in ensuring that the IOA remains responsive, relevant, and impactful, supporting rural and regional communities while advancing sustainable agricultural practices worldwide.

The 19th annual Industry Forum, held in July 2025, was a significant event in our calendar. This year, the Forum provided an important platform to examine the next 20 years of research, development and extension in agriculture. We were honoured to host Professor Fiona Wood AO, FRCS, FRACS, who delivered a distinguished overview address, offering a strategic analysis of federal funding trends in research, development, and extension over recent decades, while Dr Beth Woods complemented this perspective with insights from all rural research and development corporations. Agricultural consultant Paul McKenzie then provided some challenging comment on future research structures for the grains industry.

The event served as a constructive arena for farmers, academic researchers, and industry stakeholders to engage in dialogue on the current landscape and potential future directions of agricultural research, development, and extension.

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

I look forward to the IAB continuing to partner with IOA to achieve our shared goals in 2026 and beyond. Thank you to all members of the IAB, IOA contributors, and Director Professor Kadambot Siddique and his team.

Dr Terry Enright

Chair of the IOA Industry Advisory Board



At a time when sustainable food systems and climate resilience are defining global priorities, The UWA Institute of Agriculture (IOA) plays a central role in positioning UWA at the forefront of research-driven agricultural solutions.

Through its leadership and strategic coordination, IOA provides the framework that enables this work to succeed. This commitment to research excellence has enabled UWA to retain its position as the leading university in Australia for Agricultural Science and ranking 13th globally in the 2025 Shanghai Academic Ranking of World Universities.

Sustained excellence at this level reflects not only the strength of individual research programs, but also the Institute's ability to unite diverse expertise in sustainability, food security, climate resilience, social impact and data-driven innovation.

A particular highlight this year was the international recognition of the IOA Director Professor Kadambot Siddique, who received the 2024 Crawford Medal in May 2025 and was awarded a Doctor of Science (honoris causa) by Kerala Agricultural University, his alma mater in India. These honours reflect distinguished leadership and reinforce the global standing of UWA's agricultural research community.

The IOA Annual Research Report 2025 showcases a wide range of initiatives addressing priorities in sustainable agriculture and food systems. The Institute continues to cultivate strong collaborations with industry, grower groups, government agencies, fellow UWA institutes and schools, and leading universities worldwide. These partnerships ensure that research outcomes translate into practical benefits for communities, industries and the environment.

Effective communication remains a cornerstone of IOA's mission. Through public events, media engagement, digital platforms, and publications, IOA enhances the visibility and impact of UWA's research both nationally and internationally. The organisation of, and active participation in, major industry events provide valuable opportunities for direct engagement with industry partners and reinforces sustained connections with the Western Australian agricultural sector.

I would like to thank IOA and its affiliated researchers for their dedication and achievements throughout 2025 and look forward to their continued leadership in advancing knowledge, innovation and global impact in agriculture in the years ahead.

Professor Anna Nowak

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



Freshly seeded golden wheat fields near Merredin, WA.

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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, the WA Department of Primary Industries and Regional Development (DPIRD), Commonwealth Scientific and Industrial Research Organisation (CSIRO), National Collaborative Research Infrastructure Strategy (NCRIS) facilities, 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, whom 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 Master's by coursework and dissertation project students and PhD students.

As is evident from the projects in this chapter of the annual research report, we research a broad range of crops, including wheat, barley, canola, lupins, chickpea, field pea, rice and pasture legumes. Historically, our research has been centred on these broadacre cropping systems, reflecting Australia's major agricultural production landscape. More recently, however, we have seen increasing demand from the horticultural industry

for access to advanced phenotyping, controlled environment, and molecular analytics capabilities. Expanding our activities to support horticultural research complements our existing broadacre programs, broadens the impact of our infrastructure, and enables translation of technologies across diverse cropping systems, thereby strengthening national agricultural research capacity. New and emerging crops are also often a focus. Research is generally targeted at the dryland farming systems of WA and southern Australia, while increasingly expanding to address the needs of horticultural production systems through advanced phenotyping, controlled environment research, and multi-omics capabilities. However, northern Australia and our neighbours in Asia, including China, Timor-Leste, Bangladesh, India, Indonesia and Vietnam, are also included in these studies.

UWA researchers are involved in projects focused on topical areas, including maximising sustainable yield, thermal tolerance (frost and heat), crop water-use efficiency, disease resistance/susceptibility, the use of UAVs (Unmanned Aerial Vehicle), big data, and precision agriculture. UWA is also fortunate to have world-class facilities and very significant research strength in genomics

Theme Leaders

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and other technologies applicable to crop breeding, including accelerated single-seed descent, speed breeding, and CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats)-based approaches. A particular focus is placed upon root and rhizosphere biology, including root architecture and the role of roots in stress tolerance. 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 and phenotyping 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.

Time-series changes in the transcriptome of flowers associated with heat stress during the early reproductive stages in *Brassica napus*

Project team: Professor Wallace Cowling¹ (project leader; wallace.cowling@uwa.edu.au), Hackett Professor Kadambot Siddique¹, Dr Xiaoke Ping¹, Dr Sheng Chen¹, Xiaojie Hu¹

Collaborating organisations: ¹UWA; ²Sichuan Agricultural University, China

Heat stress severely reduces grain production in *Brassica napus* (canola/oilseed rape), particularly during early reproductive development when pollination, fertilisation, and early embryo growth are highly temperature sensitive. Transcriptomic responses were investigated in flowers of four *B. napus* cultivars exposed to transient heat stress during fertilisation and early embryo development. After hand-pollination of the 2nd to 5th florets, plants were subjected to either control conditions (25 °C/15 °C) or transient heat stress (32 °C/22 °C) for seven days, and seed yield was assessed at maturity. The cultivars Alku, AV-Ruby, YM11, and ZY821 showed contrasting heat sensitivity.

A total of 36,933 differentially expressed genes (DEGs) were identified across four cultivars and four time points (zero, one, three and six days after heat treatment), representing the first time-series transcriptomic analysis of heat stress during early reproductive development in *B. napus*. Distinct heat-responsive pathways were activated in a time-dependent manner. The heat-resilient cultivar AV-Ruby showed enrichment of unique DEGs in DNA repair and antioxidant defence pathways. At the same time, three heat shock proteins were consistently upregulated in all cultivars, indicating a core heat stress response.

Overall, this study provides a foundation for understanding the molecular mechanisms underlying heat stress resilience during the reproductive stage in oilseed rape.

This research is supported by the Chinese Scholarship Council (CSC), GRDC and UWA.



Xiaojie Hu submitted her PhD thesis in 2025.



Aborted seeds after heat stress.

Impact of heat stress on reproductive stages (pre-anthesis, anthesis, and post-anthesis) in *Brassica napus*.

Pre-anthesis



- ↓ Flower number and size
- ↑ Abnormal gametophyte development
- ↓ Pollen viability
- ↑ Ovule sterility
- ↓ Flower fecundity
- ↑ Abnormal floral structures and functions

Anthesis



- ↓ Anther dehiscence
- ↓ Pollen-stigma adhesion
- ↓ Pollen germination rate
- Disrupted pollen tube elongation

Post-anthesis



- ↓ Grain filling duration
- ↑ Defective embryos
- ↑ Inviabile seeds
- ↑ Pre-harvest sprouting seeds
- ↓ Photosynthesis
- Modified seed oil content and lipid composition

Sequencing historical isolates of agriculturally and environmentally damaging plant viruses

Project team: Adjunct Professor Roger Jones¹ (project leader; roger.jones@uwa.edu.au), Emeritus Professor Adrian Gibbs², Dr Adrian Fox³, Dr Ian Adams³, Dr Mohammad Hajizadeh⁴, Dr Jan Kreuze⁵, Dr Segundo Fuentes⁵, Karima Ben Mansour⁷, Professor Paul Guy⁸, Dr Heiko Ziebell⁹

Collaborating organisations: ¹UWA; ²ANU; ³FERA Science LTD, UK; ⁴University of Kurdistan, Iran; ⁵International Potato Centre, Peru; ⁶National Agrarian University, Peru; ⁷University of Life Sciences, Czech Republic; ⁸University of Otago, New Zealand; ⁹Julius Kuehn Institute, Germany

This ongoing project arose from the need to sequence the genomes of historical isolates of agriculturally and environmentally damaging plant viruses that were studied before nucleic acid (RNA and DNA) sequencing became widely used in the early 1990's.

The tymoviruses are a genus of viruses of dicotyledonous angiosperms, transmitted and spread by leaf-eating beetles as well as sometimes by seed or contact. More than 30 virus species of the genus Tymovirus have now been isolated, mostly from dicotyledonous plants. They occur in all continents, but few have been reported from more than one continent, suggesting that most have not yet spread by international trade in infected plant materials. Most tymoviruses cause mosaic and mottling symptoms, and their symptoms in wild plants are often very noticeable, which may be the reason so many different ones have been isolated from uncultivated plants. Forty new genomic sequences were obtained from preserved specimens of historical tymovirus isolates collected between the early 1960s and 1985, and 14 more were sequenced from newer isolates from South America and Europe. They were compared with the sequences from

Maximum Likelihood phylogeny of the Andean potato latent (APLV), Andean mild mosaic virus (APMMV) and tomato yellow blotch (ToBIMV) clusters of tymoviruses based on their CP gene sequences. New sequence accession numbers from this study are coloured red. The colour-coded ellipses indicate the countries of origin for each isolate. North to south, they are Colombia, gold; Ecuador, magenta edged with gold; Peru, magenta; Bolivia, magenta edged with green; Brazil, green; Argentina, blue; 'Andes region' (i.e. country unspecified), 'autumn orange'; UK, grey.

69 others from GenBank using maximum likelihood phylogenetic trees.

These phylogenies showed that the basal divergence of tymoviruses occurred in a population infecting Eurasian brassicas (rosids), and more recently, one of the basal lineages diversified and adapted to infect solanaceous (asterid) plants and crops of Central and South America. Heuristic comparisons based on patristic distances, branching patterns and external events suggested that the 'most recent common ancestor' of all known tymoviruses existed before the last Ice Age.

Some tymovirus lineages reached the Americas about 15,000 years ago. However, most spread of the few tymoviruses now found on more than one continent occurred during the past two centuries. Population genetic analysis found significant evidence of population contraction in the tymovirus populations infecting asterid hosts in the Americas. It also found their replicase and coat protein genes were significantly negatively selected. By contrast, their overlapping movement protein genes were positively selected which may help them adapt to new host species, including infecting economically significant crops such as cultivated brassica species, potato, tomato and eggplant.

In summary, the tymoviruses probably emerged before the last Ice Age, infecting Brassicas in Eurasia, and subsequently established diverse populations in crop and wild solanaceous plants, especially in the Americas, and in legumes in Africa, Southeast Asia, and Australia, with their hosts and vectors having previously established relationships. Positively selected changes in their movement protein genes are probably involved in their adaptation to new plant host species, including economically important crop plants. Therefore, rather than focusing only on individual viruses, this approach greatly increases the value of such studies to national and international biosecurity authorities by deepening understanding of the global origins and dissemination of an entire virus group.

This research is supported by the International Potato Centre, the CGIAR Research Program on RTB, CGIAR trust fund contributors, PPNIA (contract no. 029-2015-INIA-PNIA/UPMSI/IE), the UK DEFRA Future Proofing Plant Health Project under the Defra-Fera Science Ltd. long-term services agreement, and the EUPHRESKO VirusCurate project.



Manual weed pulling in a dryland farming system.

A next-generation analytics to improve profit from integrated weed management

Project team: Dr Mike Ashworth² (project leader; mike.ashworth@uwa.edu.au), Dr John Duncan², Professor Ken Flower^{1,2}, Associate Professor Nik Callow¹

Collaborating organisations: ¹UWA; ²AHRI; ³Queensland Department of Agriculture & Fisheries

Weeds are a major cost to Australian dryland farming enterprises, increasing input and labour costs, which in turn affect yield and grain quality and squeeze profits. Added to this is increasing herbicide resistance, undermining the reliability of once-dependable products. Despite these challenges, traditional agronomic practices have remained, with managers working reactively, treating weed outbreaks when it's the buried seedbank that needs to be monitored and controlled.

What would weed management look like if we could predict where and when weeds would emerge? The research team utilised this information in the planning phase to employ every tool available (tailored pre-emergent mixes and application, site-specific seeding rates, competitive varieties in weedy zones, and strategic

spray-topping) to achieve improved, longer-lasting control. With the result being less reliance on herbicides due to minimal weed seed set and the weed seedbank in decline?

Today's weed control tools, such as camera-guided sprayers and site-specific applications, help reduce chemical use and improve timing. However, they still focus on herbicides and treat the weed outbreaks rather than the underlying cause. A new national project led by the AHRI at The University of Western Australia with investment from the GRDC, aims to flip the script from "spray what you see" to "predict what will grow". By combining spatial imagery, farm records, and weed biology, this project will forecast the location, size and spread of likely weed patches before they appear. Pre-armed with this knowledge, farmers and consultants can apply a well-thought-out, pre-emptive, integrated weed management program, allocating valuable herbicide chemistry where it delivers impact and maximising crop competition, delivering greater efficiencies across the farming system.

AHRI has developed a new weed-prediction model that uses satellite imagery (Sentinel-2 and Planet) to monitor crop and weed signals throughout the season and across extended crop rotations (approximately five years) and flags vegetation anomalies associated with high-density weed patches. Partnering with Farmanco in Western Australia, we are validating the model using growers' fields to record weed density, species mix, and the underlying soil weed seedbank.

From this research, AHRI hopes to predict weed dynamics in growers' fields, rather than simply reacting to them, to turn predicted weed maps into management plans.

This research is supported by GRDC.

Mitigating nitrate leaching using dicyandiamide and acidified ammonium sulphate solid digestate in Western Australian sandy soil

Project team: Dr James O'Connor¹ (project leader; james.oconnor@uwa.edu.au), Professor Nanthi Bolan¹, Anna Osmond¹

Collaborating organisation: ¹UWA

Food waste represents a growing global sustainability challenge, contributing an estimated 8-10 per cent of global greenhouse gas (GHG) emissions from productions through disposal. As atmospheric CO₂ and N₂O concentrations continue to rise, innovative strategies to valorise food waste while reducing agricultural emissions are urgently needed. Anaerobic digestion offers a promising avenue in food waste management, utilising anaerobes to produce biogas methane and liquid digestate. However, the raw liquid digestate is often dilute, alkaline and prone to nitrogen losses via ammonia volatilisation. Recent advances in acidifying digestate formed concentrated solid fertiliser alternatives with stabilised ammonium, improving storage and nutrient density. However, nitrate (NO₃⁻) leaching remains a critical environmental concern when using these products, particularly in sandy soils with low cation exchange capacity.

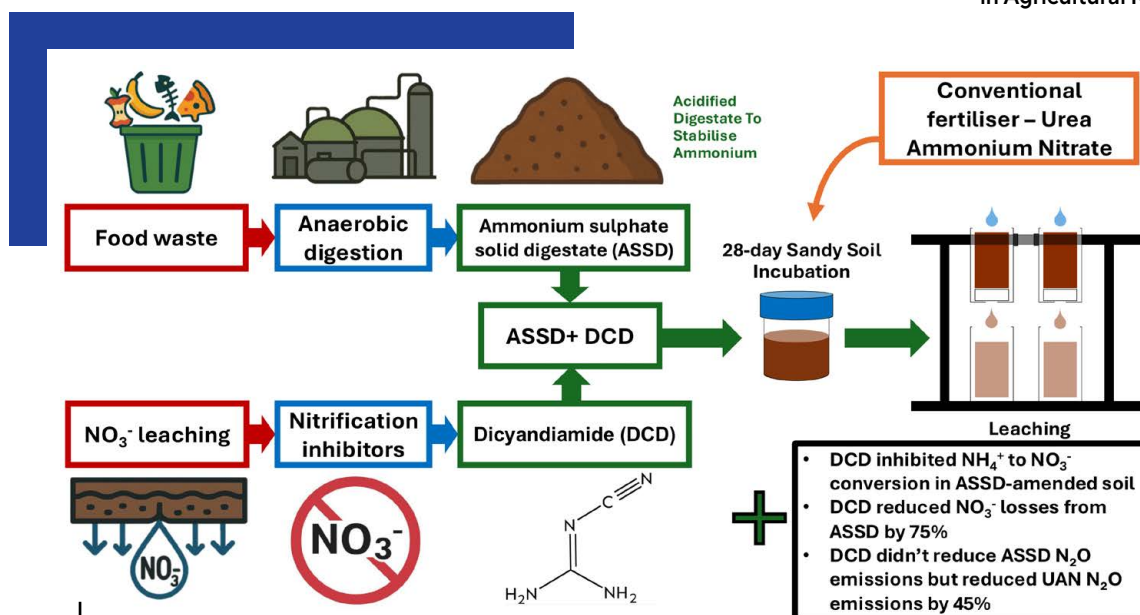
This project aimed to assess whether the nitrification inhibitor dicyandiamide (DCD) can improve soil nitrogen retention and reduce GHG emissions when applied with ammonium sulphate solid digestate (ASSD) in comparison to conventional urea ammonium nitrate (UAN) fertiliser. Three hypotheses guided the study: (1) DCD would suppress nitrification and slow the conversion of NH₄⁺ to NO₃⁻ in ASSD-amended soil; (2) reduced NO₃⁻ formation would lower leaching losses and (3) DCD would subsequently mitigate N₂O emissions from ASSD nitrogen transformations in soil. Two 28-day soil incubations and a leaching trial were conducted using sandy soil from Shenton Park, incorporating five treatments (control, UAN, UAN+DCD, ASSD, ASSD+DCD).

Results demonstrated that DCD effectively suppressed nitrification across fertiliser treatments, significantly reducing NO₃⁻-N leaching by 75.5 per cent for ASSD and 34.1 per cent for UAN. DCD also reduced N₂O emissions from UAN by 44.6 per cent, though no significant effect was observed in ASSD-treated soil. CO₂ emissions were unaffected by DCD but ASSD alone showed lower CO₂ emissions compared to the control during early incubation.

This suggested potential microbial suppression due to acidity or negative priming effects. These findings provide the first evidence of how DCD interacts with an acidified waste-derived fertiliser and highlight the importance of soil pH and microbial dynamics in shaping nitrogen transformations.

This research contributes a novel understanding of how nitrification inhibition can enhance the environmental performance of recycled food-waste fertilisers. By improving nitrate retention and reducing leaching losses, DCD offers a practical pathway for nutrient efficiency in waste-derived fertiliser products such as ASSD. The outcomes support the development of more sustainable cropping systems, particularly in sandy soils vulnerable to nutrient loss. Future work should investigate soil amendments to mitigate acidification effects and improve soil cation exchange capacity. Additionally, evaluating the performance of nitrification inhibitors such as DCD under diverse field conditions to guide the development of climate-smart fertiliser strategies.

This research is supported by DAFF Soil Science Challenge Grants Program and UWA Sir Eric Smart Honours Scholarship in Agricultural Research.

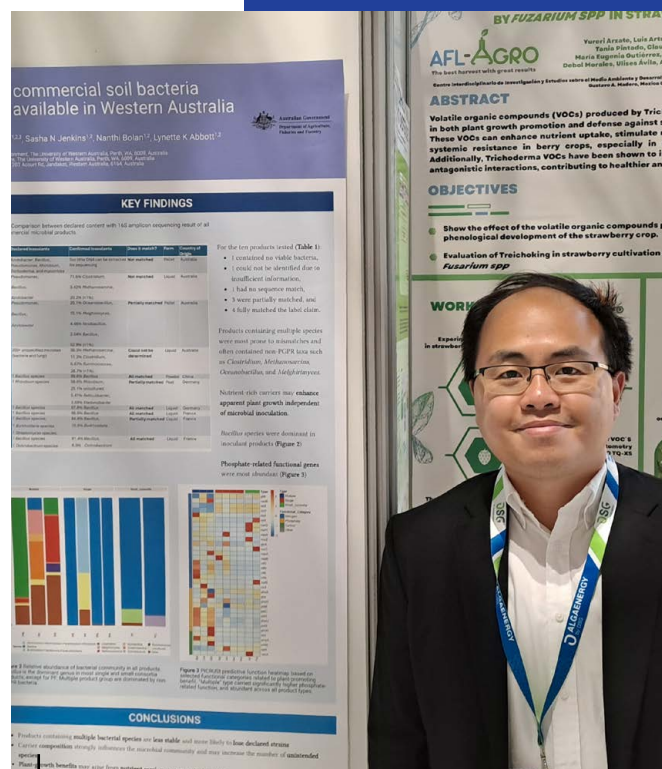


Leaching apparatus collecting leachate from soil columns to assess nitrogen losses. Experiment was performed by Anna Osmond during February-March 2025.

Graphical abstract summarising the project background information and process.



PhD student Richard Ang monitoring the pot experiment in the greenhouse at UWA after five weeks.



PhD student Richard Ang presented a poster at the Biostimulant World Congress 2025 in Barcelona, Spain.

Evaluating commercial bacterial inoculants in Western Australia: Product composition and efficacy on wheat biomass and soil properties

Project team: Richard Anthony Ang¹ (project leader; richard.ang@research.uwa.edu.au), Dr Bede Mickan^{1,2}, Dr Sasha Jenkins¹, Professor Nanthi Bolan¹, Emerita Professor Lynette Abbott¹

Collaborating organisations: ¹UWA; ²Richgro Garden Products

Plant-growth-promoting soil bacteria have the potential to benefit crops by increasing nutrient availability in the soil and by producing growth-promoting substances, such as hormones and peptides. The biofertilisers market was valued at 1.57 billion USD in 2018 and is projected to grow at 12 per cent between 2022 and 2027, with nitrogen-fixing inoculants as the primary driver. However, the rapid rise in inoculant products has outpaced the rigorous quality checks and regulatory oversight that apply to other products, such as rhizobia. Inoculant efficacy also remains varied and inconsistent. Several attempts to improve the consistency of bacterial inoculants include co-application with organic amendments, assembling better consortia, and improving the formulation and delivery.

This project aims to evaluate the efficacy of commercial bacterial-based inoculants for increasing wheat biomass. Several commercial soil bacterial inoculant products were collected from retail stores and sales representatives in Western Australia. Composition analysis revealed that one product had no detectable bacteria, but only five of the 10 products studied included all declared bacterial groups. Inaccuracies were particularly evident in consortia-based products, which did not match their declared microbial compositions and carried multiple contaminants. Products may also contain high heavy metal concentration or have low pH, both of which negatively affect inoculant survivability.

One of the 5 confirmed products was selected for plant growth experiments and survival observation of bacteria in soil. When applied independently or in combination with amendments, it had no significant effect on increasing shoot biomass, soil nitrogen and phosphate availability, carbon, or total plant nitrogen and carbon. However, it significantly increased root biomass,

especially when co-applied with organo-chemical and synthetic fertiliser. Further analysis of the soil microbial community and inoculant survivability will be completed by mid-2026.

This research area highlights the urgency of standardised quality control for microbial inoculant products and improvement in bacteria detection, particularly for consortia-based products. Preliminary findings suggest that commercial bacterial inoculants may have limited effects on growth and nutrient availability. Further studies are required to identify the optimal conditions to enhance efficacy and determine whether inoculants can have a greater impact when plants are under environmental stress.

This research is supported by the Soil Science Challenge Grants Program, funded by DAFF (project No. 4-H4T24R2), and by a scholarship from the Indonesia Endowment Fund for Education.

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

Project team: Professor Wallace Cowling¹ (project leader; wallace.cowling@uwa.edu.au), Karen Nelson¹, Dr Aneeta Pradhan¹

Collaborating organisations: ¹UWA; ²AGT Pty Ltd

This project aims to backcross a new mid-season-flowering allele, LanFTc1-1208, from wild lupin P22660 (the abbreviation for this allele is “P”). The P-allele should delay flowering in commercial lupin varieties by 7- 10 days in southern Australia compared to the traditional “Ku” allele, which results in early flowering.

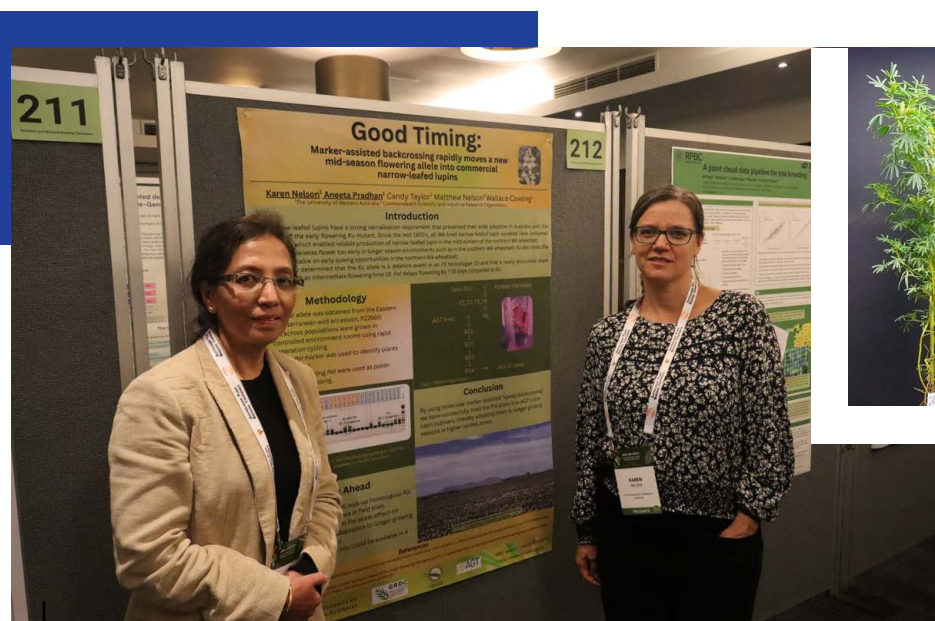
It was shown that the flowering time of BC4:S1 seedlings segregated 1:2:1 for P/P: P/Ku: Ku/Ku in most backcrosses. There was significant genetic variation in the experiment for days from emergence to flowering (DETF), number of nodes to flowering (NNTF), and plant height at flowering (PIHtF). Broad-sense heritability was very high for genetic effects controlling DETF (0.951 ± 0.013), NNTF (0.975 ± 0.007), and PIHtF (0.869 ± 0.033).

As expected, BC4:S1 progeny with Ku/Ku genotype in each backcross flowered early, with similar DETF to the recurrent AGTP-parent and Tanjil. There was a slight delay in DETF of 2-3 days in P/Ku genotypes compared to Ku/Ku genotypes. The P/P progeny flowered 13 to 21 days later than Ku/Ku progeny and at a similar time to the P22660 donor parent. It is concluded that the Ku-allele acted with incomplete dominance over the P-allele in expression of DETF in P/Ku heterozygotes, and the P-allele was fully expressed in homozygous P/P progeny and donor parent.

There was a range of expression of the DETF phenotype of P/P genotypes in different backcrosses, for example, P/P progeny in L2 (recurrent parent AGTP0214) flowered on average 7.4 days later than P/P progeny in L5 (recurrent parent AGTP0013). In the research proposal, it was hypothesised that there should be an increase in diversity of flowering time in lupin varieties with the P/P genotype compared to those with Ku/Ku. This would occur as a result of greater penetrance of

expression of alternative flowering genes in the P/P background compared to their complete lack of penetrance in the Ku/ Ku background. These results support this hypothesis, and breeders should be able to select a wide range of flowering dates in future varieties with the P/P genotype. Until now, lupin breeding programs in Australia have been dominated by the Ku/ Ku genotype, which has severely limited the range of flowering and maturity dates in lupins.

This research is supported by GRDC and COGGO.



Dr Aneeta Pradhan and Ms Karen Nelson presented a poster on the new “mid-season flowering lupin” at the Australasian Plant Breeding Conference in Fremantle in June 2025.



Backcross lupin progeny (right side) showing delayed maturity and height advantage over Tanjil (early flowering variety), and P22660, the wild lupin parent which “donated” the mid-season flowering allele LanFTc1-1208.



The UWA-based canola breeding team at field trials near Williams, WA in October 2025.
From left to right: Professor Wallace Cowling, Roz Ezzy, Jasenka Vuksic, and Dr Felipe Castro.

Pre-breeding of canola

Project team: Professor Wallace Cowling¹ (project leader; wallace.cowling@uwa.edu.au), Jasenka Vuksic¹, Rozlyn Ezzy¹, Dr Felipe Castro²

Collaborating organisations: ¹UWA; ²NPZ

In 2025, the long-standing association with the plant breeding company NPZ Lembke in Germany was continued, with projects at UWA having been funded by the company since 2000 for the pre-breeding of canola (known as spring oilseed rape or 'raps' in Germany) and field peas. These projects 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.

The canola breeding project at UWA entered a succession-planning phase in July 2025, with Professor Wallace Cowling mentoring the new NPZ canola breeder, Dr Felipe Castro, until June 2026, when Dr Castro will take over the role of canola breeder for NPZ in Australia.

During 2025, the project successfully produced more than 150 crosses in the glasshouse, following an optimised crossing design aimed at maximising hybrid performance in the progeny.

Field trials occurred at eight locations across southern Australia. They included more than 10,000 plots which were assessed for grain yield, seed oil and protein, blackleg disease resistance, and appropriate flowering and maturity dates. Field trial data were analysed with the latest statistical models to detect and select the highest-performing lines and hybrids.

This research is supported by NPZ Hans-Georg Lembke KG.

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

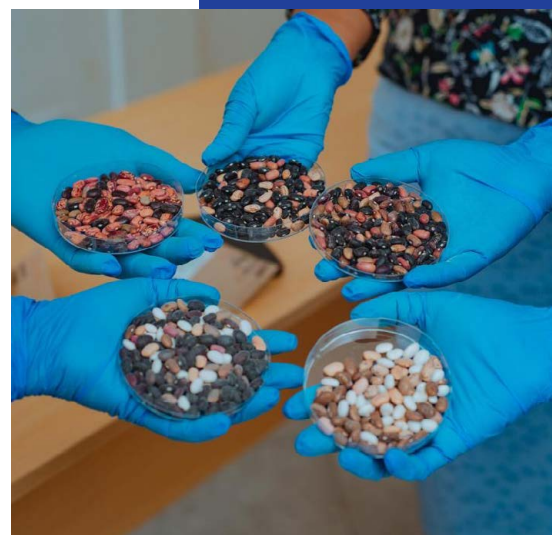
Project team: Professor Wallace Cowling¹ (project leader; wallace.cowling@uwa.edu.au), Dr Renu Saradadevi¹, Hackett Professor Kadambot Siddique¹, Dr Clare Mukankusi², Dr Winny Amongi², Jean-Claude Rubyogo³

Collaborating organisations: ¹UWA; ²Alliance-CIAT, Uganda; ³PABRA; ⁴RAB, Rwanda; ⁵EIAR, Ethiopia; ⁶SABU, Burundi; ⁷TARI, Tanzania; ⁸KARLO, Kenya; ⁹NaCRRI, Uganda

This was the sixth year of the Australian Centre for International Agricultural Research (ACIAR) project CROP/2018/132 on bean breeding in East Africa. The project aims to implement new rapid breeding methods to reduce cooking time (CKT) by 30 per cent and to increase Fe by 15 per cent and Zn by 10 per cent in five years, while maintaining or increasing grain yield (GY). A major goal is capacity building in plant breeding and training in gender-inclusive skills for the breeding and release of the new cultivars that are adopted quickly by African farmers and the food industry. The key development

issues in sub-Saharan Africa that the team seek to address in this project are poor food nutrition associated with anaemia and stunting in African women and children, and the time, economic losses and negative health and environmental impacts associated with cooking beans.

In 2024-25, the results showed in multivariate linear mixed models of genomic and phenotypic data that rapid genetic gain was achieved in reducing CKT during the project. CKT decreased on average by 22 per cent over two years in two breeding populations (11 per cent per year), while GY also improved slightly. The expectation is to maintain this rate of genetic gain in CKT and GY in the future, but the project must also mitigate several detrimental genetic correlations between CKT and other traits, such as Fe, Zn, seed size, and seed colour. This is possible in the BRIO breeding system, where weighting on selection for Fe, Zn, and seed size/colour can be managed in the index to achieve long-term genetic gain in all traits with OCS.



Training in Uganda (March 2025) shows a wide range of seed colours found in progeny of diverse crosses in the project.

During the year, interesting new selections of rapid-cooking beans were made by breeders and agronomists in six PCs, matching market demands for high GY and preferred seed colours. Bulking and evaluation of new varieties were underway in PCs at the end of 2025.

Training occurred in March 2025 at Alliance-CIAT in Uganda, where Dr Renu Saradadevi (Research Associate, UWA) updated bean breeders from Uganda and Ethiopia on optimised crossing designs for market classes in beans.

This research is supported by ACIAR.



Training in Uganda (March 2025) for optimised crossing designs in beans for market classes, with Dr Renu Saradadevi from UWA IOA (left) and project team members from Uganda and Ethiopia.



Depth-based sampling at anthesis (Zadoks 65) to evaluate root penetration and soil physicochemical properties.

Influence of surface-incorporated humate-based lime on subsoil acidity and wheat (Scepter) growth

Project team: Professor Nanthi Bolan¹ (project leader; nanthi.bolan@uwa.edu.au), Oshadi Hettithanthrige Dona¹, Hackett Professor Kadambot Siddique¹, Associate Professor Zakaria Solaiman¹, Andrew Doecke²

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

Soil pH is a key soil-health attribute because it controls nutrient solubility and root microbe interactions. A slightly acidic to neutral pH generally maximises the availability of macronutrients (e.g., N, P and S). In contrast, very acidic or alkaline conditions can cause nutrient deficiencies or toxicities, particularly aluminium (Al) and manganese (Mn) toxicity in strongly acidic soils, thereby reducing crop productivity. Subsurface soil acidity is widespread globally, and in Australia it is a major constraint in the grain belt of south-western Western Australia, where severe acidity often extends deeper into the soil profile. This is a major limiting factor for wheat production, one of Australia's most important grain crops and a significant contributor to human dietary energy. Therefore, improving wheat growth parameters such as tillering, biomass, nutrient uptake and yield components is critical for food security and for enhancing nutrient-use efficiency.



PhD student Oshadi Hettithanthrige Dona is assessing wheat plant performance in response to humate-based lime treatments under glasshouse conditions at UWA.

Conventional liming is the most common practice for managing soil acidity; however, it often requires large application rates. The effects of surface-applied lime, such as increased soil pH and reduced exchangeable Al, are typically confined to only a few centimetres below the incorporation depth. This indicates that the downward movement of calcium (Ca) through the soil profile is extremely slow. The distance Ca moves depends on lime reactivity, which is largely controlled by dissolution and how well the lime is distributed through the soil. Limited evidence suggests that combining lime with organic amendments may enhance the downward movement of alkalinity. In this context, humic substances (humic acid, fulvic acid, and their salts) are increasingly discussed as supplementary amendments for soil acidity management, due to their ability to mobilise and complex metals, particularly monomeric Al³⁺, a major constraint on root growth in acidic soils. While lime-humate combinations may have synergistic effects, this approach remains poorly studied.

This PhD project addresses this knowledge gap by developing and testing novel humate-based lime to ameliorate subsoil acidity and improve soil health and

crop productivity. A major milestone achieved in 2025 was the completion of a comprehensive glasshouse experiment that evaluated soil physicochemical properties at multiple depths, as well as wheat growth and grain yield responses, using dolomite amended with humic substances across a range of application rates.

The results indicate that surface application of dolomite combined with humate/fulvate created more favourable conditions for microbial activity and promoted the downward movement of alkalinity into the subsoil, resulting in increased pH. This treatment also increased cation exchange capacity (CEC), raised exchangeable Ca and exchangeable Mg, and reduced exchangeable Al in both the topsoil and subsoil layers. In addition, it promoted deeper root growth. Most importantly, the treatments could improve nutrient uptake by the shoots.

These outcomes provide important insights into the practical application and potential scalability of lime-humate treatments for mitigating subsoil acidity and Al toxicity, while also supporting broader improvements in soil health and plant growth.

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

Annual Legume Breeding Australia (ALBA)

Project team: Associate Professor Phillip Nichols¹ (project leader; philip.nichols@uwa.edu.au), Bradley Wintle¹, Professor Megan Ryan¹, Dr Judith Lichtenzveig¹, Dr Maria Pazos-Navarro¹

Collaborating organisations: ¹UWA; ²DLF Seeds

Annual Legume Breeding Australia (ALBA) is a joint venture between UWA and the pasture seed company, DLF Seeds. ALBA aims to breed improved cultivars of annual pasture legumes for farmers in southern Australia and other international markets. Key species include subterranean clover (sub clover) (*Trifolium subterraneum*), balansa clover (*T. michelianum*), Persian clover (*T. resupinatum*) and arrowleaf clover (*T. vesiculosum*).

The first ALBA products will be sold commercially by DLF Seeds in 2026. Certified seed of the late-flowering 'Edison' sub clover and the water-logging-tolerant 'Franklin' ssp. *Yanninicum* sub clover is being marketed, while the mid-late flowering 'Carver' is undergoing certified seed production.

Breeders' seed was produced at the UWA Shenton Park Field Station in 2023 and 2024 of four new annual clovers. These include: 'Adder' and 'Python', late-flowering and midseason balansa clovers, respectively; 'Typhoon', Persian clover var. majus; and 'Warrior', midseason arrowleaf clover. Further multiplication of these cultivars is being undertaken by DLF Seeds in eastern Australia.

Breeders' seed of a new early-flowering sub clover, code-named 'SE035', was conducted at Shenton Park in 2025. This follows strong performance over three years in field trials at the UWA Ridgefield Farm and sites in NSW and Victoria.

A new midseason sub clover has also been selected for breeders seed production in 2026, following excellent performance over three years at Boyup Brook and in Victoria and NSW.

Field trials of an elite cohort of mid-season sub clover ssp. *Brachycalycinum* have been sown at Manjimup and Boyup Brook and at sites in NSW and Victoria. This subspecies has the potential for outstanding biomass production but does not actively bury its burrs.

This research is supported by DLF Seeds.



Brad Wintle with the Breeders seed crop of 'SE035' early-flowering sub clover at Shenton Park Field Station.



Commercial seed production of the new ALBA sub clover cultivar, 'Edison' in South Australia.

Synergistic effects of low phosphorus and polyethylene microplastic on cadmium uptake in ryegrass (*Lolium rigidum*)

Project team: Dr Yinglong Chen¹ (project leader; yinglong.chen@uwa.edu.au), Dr Xunzhe Yang^{2,3}, Dr Ping Yun¹, Dr Shuo Liu^{1,4}, Professor Haiqin Zhang², Professor Yonghong Zhou², Professor Sergey Shabala¹

Collaborating organisations: ¹UWA; ²Sichuan Agricultural University, China; ³Chinese Academy of Sciences, China; ⁴Chinese Academy of Agricultural Sciences, China

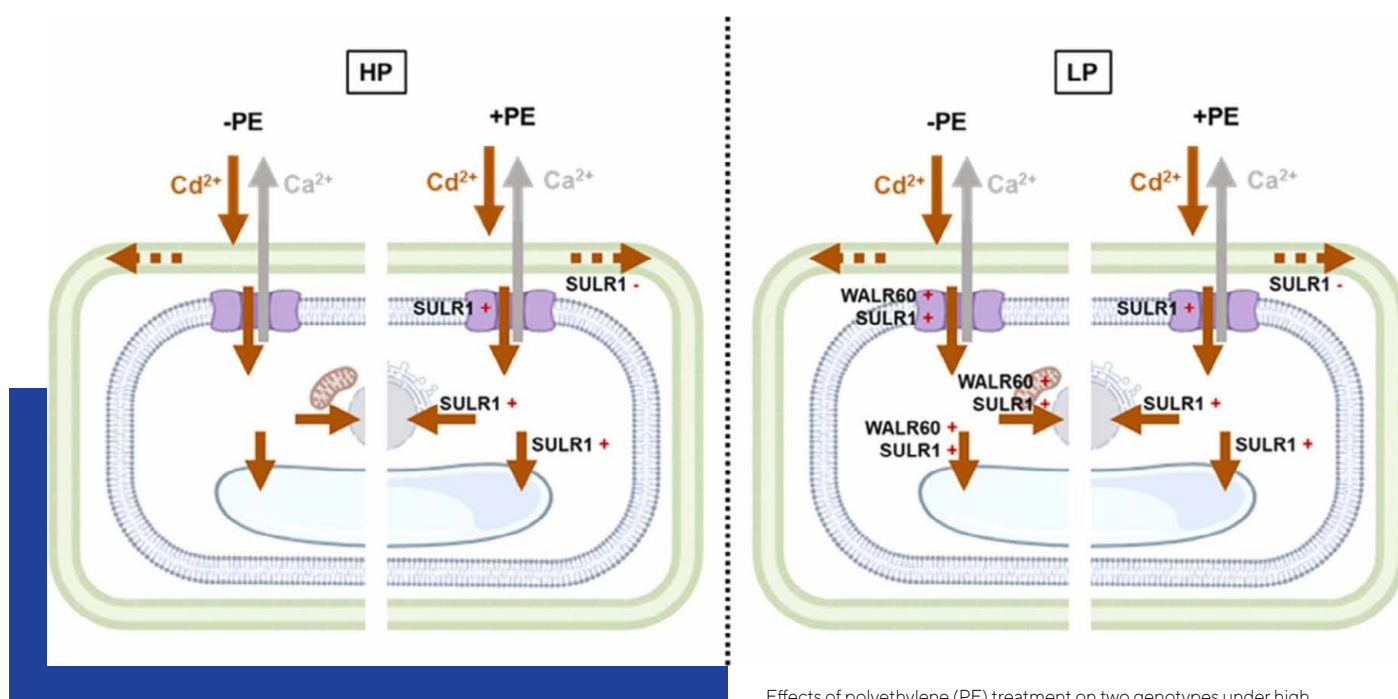
Soil cadmium (Cd) contamination poses significant risks to plant production and human food safety. Lands contaminated with Cd are often also at risk of co-contamination with microplastics (MPs) or low phosphorus (LP) content. Additionally, herbicides and Cd share related efflux transporters in the ABC gene family, and both, along with MPs, are mediated by NADPH. However, the potential connections between these factors remain unclear.

This study used two herbicide-extreme genotypes of ryegrass (*Lolium rigidum*) (herbicide-tolerant and herbicide-sensitive) to explore whether MPs and LP could influence plant Cd uptake and accumulation further, and to investigate the relationship between herbicide-extreme genotypes and Cd or MP stress. The findings were as follows:

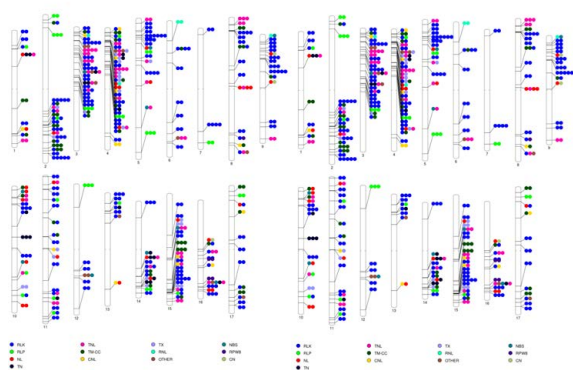
- 1) Although there was no difference in Cd uptake and accumulation between the two genotypes, herbicide tolerance and MP tolerance were similar.
- 2) The interaction of LP and MPs further enhanced Cd uptake and accumulation in plants.
- 3) For elements such as P and Ca, no significant interaction between Cd, LP, and MPs was observed; rather, the effect should be considered as "Cd + LP × MP".
- 4) The significant combined effect of Cd × LP × MP on the biomass of the sensitive genotype might be the result of multiple regulatory networks working together.

This study enhances the understanding of plant responses to combined stresses and provides valuable guidance for addressing complex pollution scenarios involving Cd, LP, and MPs in the future.

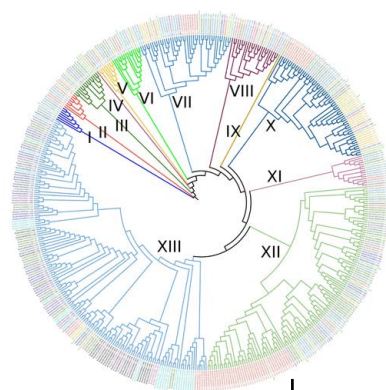
This research is supported by ARC (FT210100902), GRDC (DAW2407-001SPX) and CSC (202206910046).



Effects of polyethylene (PE) treatment on two genotypes under high phosphorus (HP, a) or low phosphorus (LP, b) treatment. Cell walls locked Cd²⁺ to mitigate Cd toxicity.



Physical clustering of RGAs in *B. carinata* C4012_v1 (left) and 10167_v1(right) assemblies. Chromosomes labelled 1 to 17, corresponding to B1–B8 for the B sub-genome and C1–C9 for the C sub-genome.



Phylogenetic analysis of NLR genes identified in *B. carinata* C4012_v1 (left) and 10167_v1(right) assemblies.

Resistance gene analogues identification and comparative genomic analysis of *Brassica carinata* genomes

Project team: Professor Jacqueline Batley¹ (project leader; jacqueline.batley@uwa.edu.au), Dr Aria Dolatabadian¹, Chenyu Li¹, Dr Mitchel Bestry¹, Professor David Edwards¹

Collaborating organisation: ¹UWA

Brassica carinata is an emerging allotetraploid oilseed crop valued for its resilience to diverse biotic and abiotic stresses and its potential for sustainable biofuel production. Despite these attributes, the genomic underpinnings of disease resistance in this species have remained largely unexplored. To address this gap, a comprehensive genome-wide survey of resistance gene analogues (RGAs) was conducted in two assembled *B. carinata* genomes (C4012_v1 and 10167_v1) using the RGAugury pipeline, enabling detailed classification, chromosomal mapping, and evolutionary interpretation of key immune-related gene families.

Across the two assemblies, 2,498 (C4012_v1) and 2,685 (10167_v1) RGAs were identified, encompassing receptor-like kinases (RLKs), receptor-like proteins (RLPs), transmembrane-coiled-coil proteins (TM-CCs), and nucleotide-binding leucine-rich repeat (NLR) genes. RLKs were the most abundant class, constituting over half of all RGAs in each genome, followed by TM-CCs and RLPs. NLRs and their subclasses were less numerous but displayed substantial diversity. RGA distribution across chromosomes was highly uneven, with notable hotspots on B2 and C3 in both assemblies, reflecting patterns observed in other *Brassica* species. These regions, enriched for immune-related loci, may represent key sites for resistance gene diversification.

Duplication analysis revealed that RGA expansion in *B. carinata* has been strongly shaped by both tandem and segmental duplication events. In C4012_v1 and 10167_v1, respectively, 88 per cent and 89 per cent of RGAs displayed evidence of duplication, with the majority participating in intergenomic duplications between the B and C sub-genomes. TM-LRR families, including RLKs and RLPs, accounted for most duplicated loci, while NLRs also exhibited extensive duplication, consistent with their dynamic evolutionary histories. The number of tandem and segmental events was similar between sub-genomes, highlighting parallel evolutionary trajectories following polyploidisation.

Physical clustering further underscored the structural organisation of R genes in these genomes. In C4012_v1, 19 per cent of RGAs formed 216 clusters, while 22 per cent were organised into 243 clusters in 10167_v1. Both genomes exhibited mixtures of homogeneous clusters, containing either TM-LRR or NLR genes exclusively, and heterogeneous clusters combining different RGA classes. Such clusters likely facilitate recombination, gene conversion, and the emergence of novel resistance specificities. The prevalence of mixed TM-LRR/NLR clusters is particularly notable, as these configurations may contribute to coordinated recognition and signalling functions within the plant immune system.

Phylogenetic reconstruction of RGA families revealed multiple distinct clades, indicative of both ancient diversification and species-specific expansions. Comparative analysis against 49 cloned resistance genes from the Brassicaceae identified 51 high-

confidence homologues (C4012_v1) and 59 (10167_v1) in *B. carinata*. These included multiple copies of *At_BAK1*, a co-receptor implicated in broad-spectrum defence, suggesting potential functional redundancy or diversification that could be leveraged for crop improvement.

This study provides the first detailed catalogue of RGAs across two *B. carinata* genome assemblies, offering new insights into their distribution, duplication dynamics, and evolutionary relationships. The findings lay the foundation for identifying candidate resistance genes for functional validation and support future molecular breeding and genome-editing strategies to enhance disease resistance and environmental resilience in this promising oilseed crop.

This research is supported by UWA.

Innovative use of phosphorus-enriched steel slag for sustainable agriculture

Project team: Professor Nanthi Bolan¹ (project leader; nanthi.bolan@uwa.edu.au), Ruwani Ruwani Hapuarachchige¹, Hackett Professor Kadambot Siddique¹, Associate Professor Zakaria Solaiman¹, Dr James O'Connor¹

Collaborating organisations: ¹UWA; ²University of Wollongong; ³University of Newcastle; ⁴BHP Innovation PTY LTD

This PhD project investigates the potential of phosphorus-enriched industrial steel slag as a sustainable alternative phosphorus (P) fertiliser for agricultural systems.

In 2025, the research progressed from laboratory characterisation to soil-based investigations, with primary emphasis on a controlled soil incubation study. A 56-day incubation experiment was conducted using two contrasting acidic soils to evaluate phosphorus-enriched industrial steel slag (P-EISS), industrial steel slag (ISS), triple superphosphate (TSP), and ferric orthophosphate (FOP), each applied at 150 mg P kg⁻¹ soil. Periodic measurements of soil pH, electrical conductivity (EC), and plant-available phosphorus (Colwell P, CaCl₂-P, and water-extractable P) were undertaken to monitor temporal changes in P availability. Sequential phosphorus fractionation at the end of incubation provided insight into P transformation and distribution among labile, moderately labile, and stable pools.

Slag-based amendments significantly increased soil pH across both soils, confirming their liming potential. Phosphorus availability was strongly influenced by both fertiliser type and soil properties. P-EISS demonstrated phosphorus release comparable to TSP and enriched labile (NaHCO₃-P) and moderately labile (NaOH-P) fractions. In contrast, ISS and FOP were associated with greater proportions of less bioavailable P forms. These findings provide important mechanistic understanding of P dynamics in soil and strengthen the scientific basis for developing P-enriched slag materials for sustainable cropping systems.

In addition, a glasshouse rate-response experiment with wheat was conducted to determine the optimum phosphorus application rate of P-EISS compared with TSP. Plant growth and soil measurements were completed, and data analysis is ongoing.

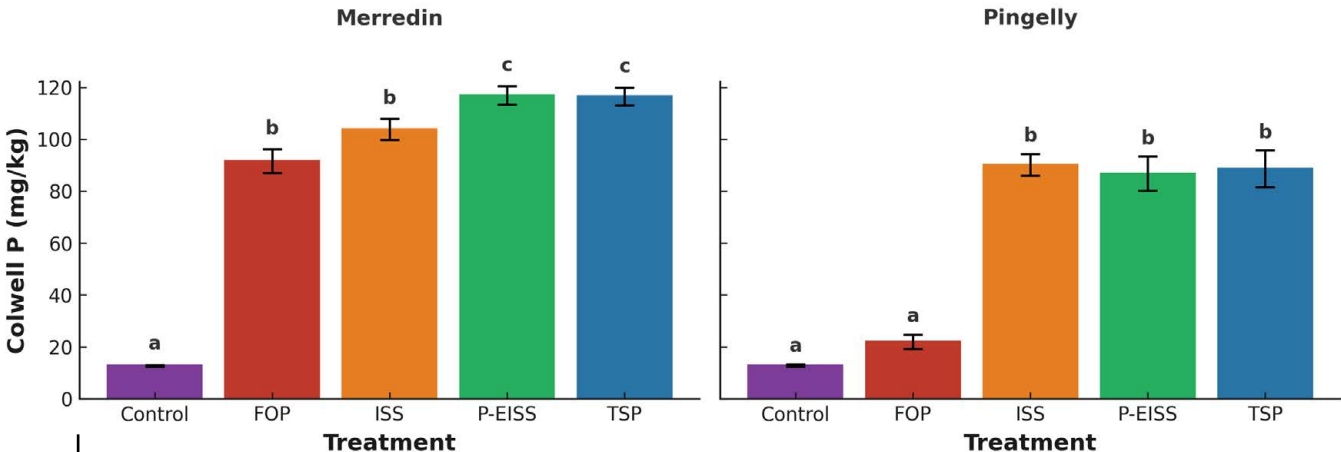
In future, a complementary soil column crop experiment will compare P-EISS and TSP at the optimum rate assessing vegetative growth, grain yield, nutrient uptake, and residual soil phosphorus status. Together, these studies aim to establish the agronomic effectiveness and environmental sustainability of phosphorus-enriched steel slag as an alternative P fertiliser for agriculture.



Conducting glasshouse study to evaluate response to phosphorus rates applied with steel slag source.

This research is supported by ARC Linkage Project funding, BHP Innovation Pty Ltd and UWA Graduate Research School.

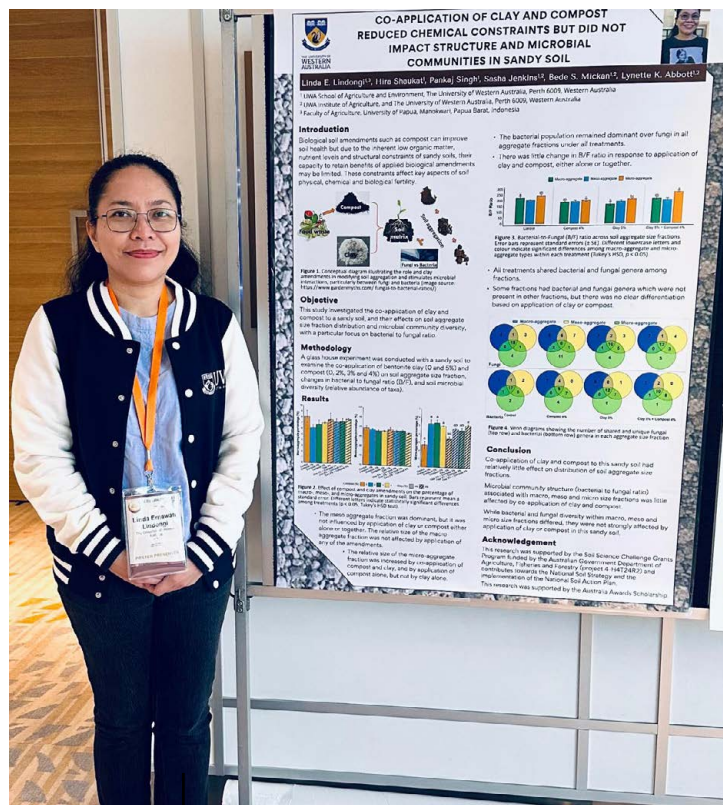
Colwell P



Mean Colwell P of different treatments in Merredin and Pingelly soil under different treatments (Control, FOP, ISS, P-EISS, and TSFP).



PhD student Linda Ernawati Lindongi with Emerita Professor Lyn Abbott in the glasshouse.



PhD student Linda Ernawati Lindongi presented a poster at the Global Conference on Sandy Soils.

Soil structural and microbial interactions in soil amended with organic fertiliser

Project team: Linda Ernawati Lindongi^{1,2} (project leader; linda.lindongi@research.uwa.edu.au), Emeritus Professor Lynette K. Abbott¹, Dr Sasha Jenkins¹, Dr Bede S. Mickan¹, Dr Hira Shaukat¹

Collaborating organisations: ¹UWA; ²University of Papua, Indonesia

Sandy soils are constrained by weak aggregation, low water-holding capacity, poor nutrient retention, and low cation exchange capacity (CEC), which together reduce biological activity, increase nutrient losses, and limit crop productivity. These physical constraints are often accompanied by chemical limitations such as acidity, low nutrient availability, and salinity. Improving both the physical and biological fertility of sandy soils is therefore essential for sustainable agricultural production.

This research investigated whether the co-application of clay and organic amendments could improve soil structure, microbial activity, and soil fertility in sandy soil. The study focused on how bentonite or kaolinite clay, combined with compost or hay residue and inorganic fertiliser, influenced soil aggregate formation,

aggregate size distribution, and the microbial communities associated with different aggregate fractions.

The first experiment showed that compost was the main driver of short-term improvements in soil chemical and biological properties, while bentonite clay appeared to play a more gradual role in soil stabilisation and aggregate development. Compost had stronger effects on microbial communities than clay, increasing bacterial abundance relative to fungi and enriching carbon-degrading genes, particularly in finer soil fractions. Although these treatments did not produce clear short-term structural improvements, distinct bacterial and fungal genera were associated with different aggregate fractions, suggesting fraction-specific microbial colonisation.

The second experiment demonstrated that organic residue inputs were the main drivers of changes in soil fraction distribution and microbial communities, whereas kaolinite clay and inorganic fertiliser made smaller supportive contributions. Bacterial communities were more responsive to organic inputs

than fungal communities. The combined application of kaolinite clay, hay residue, and nutrient inputs showed potential to improve soil structure and stimulate microbial activity in sandy soils.

Overall, the findings highlight the importance of organic amendments, particularly compost and hay residue, in improving soil fertility and plant performance in the sandy soils used.

Co-application with clay may further support these benefits by enhancing nutrient retention and structural stability. The results also suggest that longer-term responses, especially in fungal communities and aggregate development, may become more evident over time.

This research is supported by The Soil Science Challenge Grants Program (Project 4-H4T24R2) through DAFF.

Accounting for soil water improves the prediction of lentil phenology for improved frost and heat stress management

Project team: Associate Professor Yashvir Singh Chauhan² (project leader; yash.chauhan@daf.qld.gov.au), Dr Muhuddin Rajin Anwar^{3,4}, Dr Mark F Richards³, Dr Ryan HL Ip^{4,5,6}, Dr David J Luckett⁴, Dr Lachlan Lake⁷, Dr Victor O Sadras⁷, Hackett Professor Kadambot Siddique¹

Collaborating organisations: ¹UWA; ²Department of Primary Industries, QDL; ³Department of Primary Industries and Regional Development, NSW; ⁴Charles Sturt University; ⁵Auckland University of Technology, New Zealand; ⁶The University of Adelaide; ⁷Flinders University

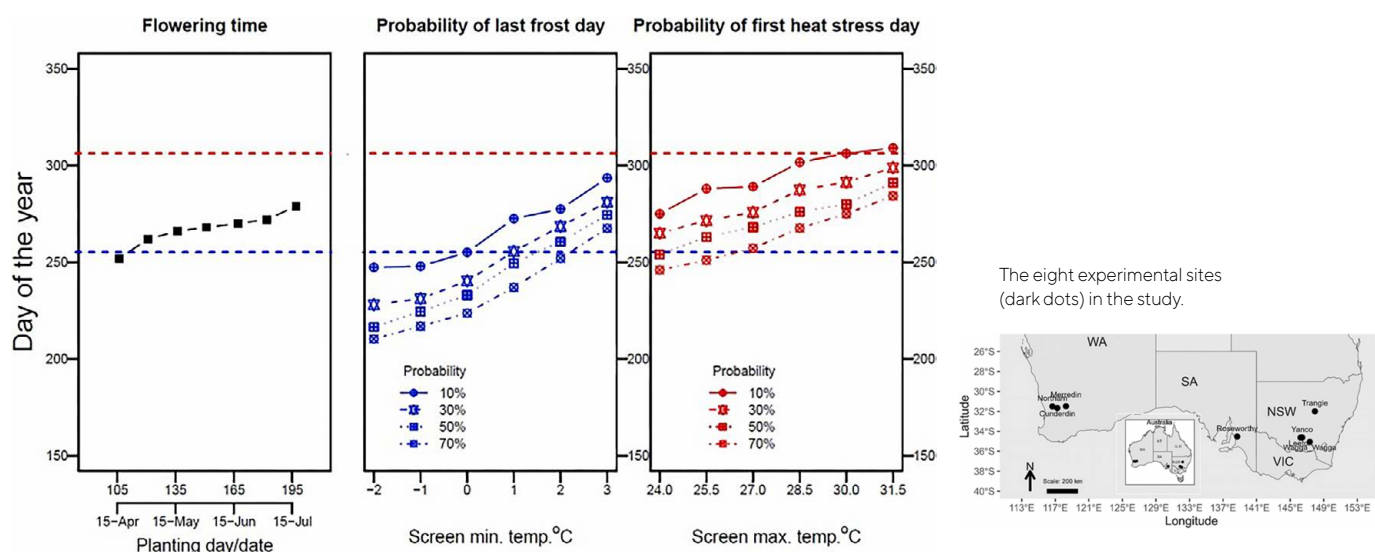
Lentils in Australia are primarily grown in temperate and Mediterranean climates, especially in the southern and western regions of the country. As in other parts of the world, lentil yields in these areas are significantly influenced by factors such as frost, heat, and drought, contributing to variable production. Therefore, selecting appropriate lentil varieties and determining optimal sowing times that align with favourable growing conditions is crucial. Accurate predictions of crop development are essential in this context.

Current models mainly rely on photoperiod and temperature to predict lentil phenology; however, they often neglect the impact of soil water on flowering and pod set. This study investigated whether incorporating soil water as an additional factor could improve predictions for these critical growth stages.

The modified model was tested using 281 data points from various lentil experiments that examined the timing of flowering (61–147 days) and pod set (77–163 days) across different combinations of location, variety, sowing time, and season. The results indicated that including soil water in the prediction model yielded R^2 values of 0.84 for flowering and 0.83 for pod set. The normalised root mean square error (NRMSE) was 0.07, and Lin's concordance correlation coefficient (LinCCC) was 0.91. The model produced an R^2 of 0.88, an NRMSE of 0.05, and a LinCCC of 0.93 for flowering, compared to the default model, which yielded an R^2 of 0.24, an NRMSE of 0.17, and a LinCCC of 0.36 for flowering. A limited sensitivity analysis of the modified model showed that variations in initial soil water and in-season rainfall significantly affected the timing of flowering and pod set.

Additionally, the study employed a probability framework to assess the crop's vulnerability to the last frost day and early heat stress events during the reproductive stage. This approach provided valuable insights for decision-making to mitigate risks associated with frost and heat stress. The study suggests that integrating soil water dynamics into lentil phenology models improves the accuracy and precision of predictions regarding the timing of flowering and pod set. These improvements lead to better forecasts, ultimately helping to minimise damage from frost and heat stress during lentil cultivation and can better explain the effect of climate variability.

This research is supported by GRDC, NSW DPI and QLD DAF.



The simulated flowering day of the year, adjusted for soil water effects, is shown by a solid dark line and solid square symbols in the left panel based on the sowing date. In the middle panel, blue lines with symbols illustrate the probabilities of the crop experiencing frost (temperatures between -2 and 3 °C). In contrast, the right panel features red lines with symbols indicating heat stress (temperatures between 24 and 31.5 °C) from 1957 to 2022. A horizontal blue line without symbols that runs across all three panels, represents day of the year with a 10 per cent probability of experiencing 0 °C (frost). Similarly, a horizontal red line marks the 10 per cent probability of experiencing heat stress at 30 °C.

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



Measuring sandalwood growth at Clacuc, Timor-Leste.



Pot trials investigating the role of biochar in alleviating constraints to plant nutrition.

Project team: Associate Professor Louise Barton¹ (project leader; louise.barton@uwa.edu.au), Rob Williams¹, Joaquina Barreto², Associate Professor David Lee³, Associate Professor Fay Rola-Rubzen⁴, Luis Pereira², Professor Nanthi Bolan¹, Associate Professor James Fogarty¹, Associate Professor Matthias Leopold¹, Professor William Erskine¹

Collaborating organisations: ¹UWA; ²AI-Com; ³University of the Sunshine Coast; ⁴Curtin University; ⁵Timor-Leste's Ministry of Agriculture, Livestock, Fisheries and Forestry

Many rural households in Timor-Leste continue to experience low and unreliable agricultural incomes, limiting opportunities to improve their livelihoods. AI-Com 2 is addressing these challenges by improving soil health, labour efficiency, and the resilience of smallholder farming systems. Building on innovations and partnerships established under AI-Com 1, the project is delivered through four interconnected themes led by UWA, in collaboration with the Ministry of Agriculture, Livestock, Fisheries and Forestry (MALFF) in Timor-Leste, the University of the Sunshine Coast and Curtin University.

Theme 1 focuses on evaluating the role of biochar in addressing soil constraints to crop production. In 2025, the MALFF-led Biochar Collective delivered 15 workshops on the use and production of biochar across seven municipalities, engaging nearly 900 farmers and extension staff. Longterm trials at Darasula continue to demonstrate that a single, large application of biochar (20 t/ha) can increase soil pH and boost crop yields even after seven years. Complementary pot studies conducted in the last year are further building our understanding of how biochar can address nutrient limitations across diverse soil types.

Theme 2 aims to improve crop productivity through labour-efficient cropping systems and conservation agriculture (CA). On-farm trials in 2024/25 evaluated the agronomic and economic benefits of CA Plus. This low-labour approach uses a non-selective herbicide before sowing and selective herbicides to control in-season weeds. While yield responses varied between locations, the practice consistently delivered labour savings and economic gains due to reduced hand-weeding.

Theme 3 supports the sustainable development of Timor-Leste's sandalwood industry. Efforts over the past 12 months

have focused on improving resource mapping and understanding what drives plantation performance. Consolidation of provenance trial data revealed major differences in survival and growth between seed sources, with some commonly planted sources growing poorly in the trials. These findings have important implications for plantation success. Based on these results, preliminary recommendations on the best seed sources to plant to improve grower success have been made.

Theme 4 explores the benefits of improved knowledge of soils, intensification, and diversification for women in agriculture. Qualitative research conducted in collaboration with MALFF socio-economists across three municipalities has identified herbicide use, adopted gradually since 2005, as the most transformative farming change of the past decade and reported benefits included reduced labour demands, expansion of cropped area, and significant increases in household income. Both men and women were involved in herbicide application and jointly made key farming decisions.

AI-Com 2 remains strongly aligned with Timor-Leste's agricultural priorities. Key constraints—poor soil fertility, limited input use, labour shortages, and the need for robust evidence to guide sandalwood management—continue to guide the project's direction.

This research is supported by ACIAR and UWA.



Paul Damon (left) and DPIRD's Jack Hughes collecting crop residue samples from Esperance for ^{15}N analysis.

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

Project team: Associate Professor Louise Barton¹ (project leader; louise.barton@uwa.edu.au), Dr Craig Scanlan¹, Paul Damon¹, Dr Tan Dang¹, Dr Yoshi Sawada¹

Collaborating organisations: ¹UWA; ²DPIRD

Optimising nitrogen fertiliser use is essential for Australian grain growers, as it represents one of the most expensive and variable costs in crop production. Despite its importance, major knowledge gaps remain regarding how nitrogen behaves in modern dryland cropping systems, including how much is taken up by crops, how much remains in the soil, and how much is lost to the atmosphere. Addressing these gaps is critical for improving crop models' ability to predict the fate of applied fertiliser nitrogen. The project focuses on three key objectives:

A national GRDC-funded project aims to strengthen our understanding of nitrogen cycling and improve crop models' ability to predict the fate of applied fertiliser nitrogen. The project focuses on three key objectives:

- 1) Quantifying the fate of fertiliser nitrogen during the year of application and in subsequent seasons across 12 national sites using ^{15}N labelled urea.
- 2) Improving understanding of nitrogen supplied from crop residue breakdown and soil nitrogen mineralisation.
- 3) Integrating new knowledge into the APSIM soil-crop simulation model to enhance decision-support tools.

In Western Australia, ^{15}N labelled urea was applied annually (2023–2025) at four sites: Esperance, Merredin, Pingelly (UWA Farm Ridgefield), and Wongan Hills. The use of ^{15}N enables researchers to track fertiliser N through the soil-plant system over multiple seasons. Initial results show that in 2023, less than 25 per cent of applied N was removed in wheat grain, while a large proportion (approx. 40–75 per cent, depending on site and fertiliser rate) remained in crop residues and the soil. The following barley crop recovered up to 22 per cent of this residual N, demonstrating a modest, but ongoing contribution to crop nutrition.

Ammonia volatilisation, a potential loss pathway for urea, was measured on four occasions during the 2024–2025 growing seasons in the central grainbelt of Western Australia. Losses ranged from <5 to 48 per cent, with the highest losses observed at Wongan Hills in 2025. These losses were linked to urea being applied to moist soil with limited pH buffering capacity, followed by very little rainfall (<2 mm) in the week after application.

The field study phase of the project is now complete. Early findings do not justify adjusting fertiliser N rates in the grainbelt of Western Australia to account for expected residual fertiliser N. Current results highlight that ammonia volatilisation can be highly variable and, under certain soil and weather conditions, represents a significant loss of fertiliser N from cropping soils in the central grainbelt of Western Australia. Data analysis and model integration are ongoing, and final recommendations will be available at the project's completion in 2027.



Tan Dang (left) and Yoshi Sawada (right) collecting soil samples at 10 cm increments at Wongan Hills for soil chemical and physical analysis.

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



Integrating farmers' views, field soil erosion assessment, and pot experiments to evaluate different agroforestry systems in Timor-Leste

Project team: Dr Marçal Gusmão^{2,3} (project leader; marcalgusmao@gmail.com), Hackett Professor Kadambot Siddique¹ (project leader; kadambot.siddique@uwa.edu.au), Zevacio Fernandes², Juvencio dos Santos², Professor Archontoulis V. Sotirios

Collaborating organisations: ¹UWA; ²National University of Timor Lorosa'e, Timor-Leste; ³Iowa State University of Science and Technology, USA

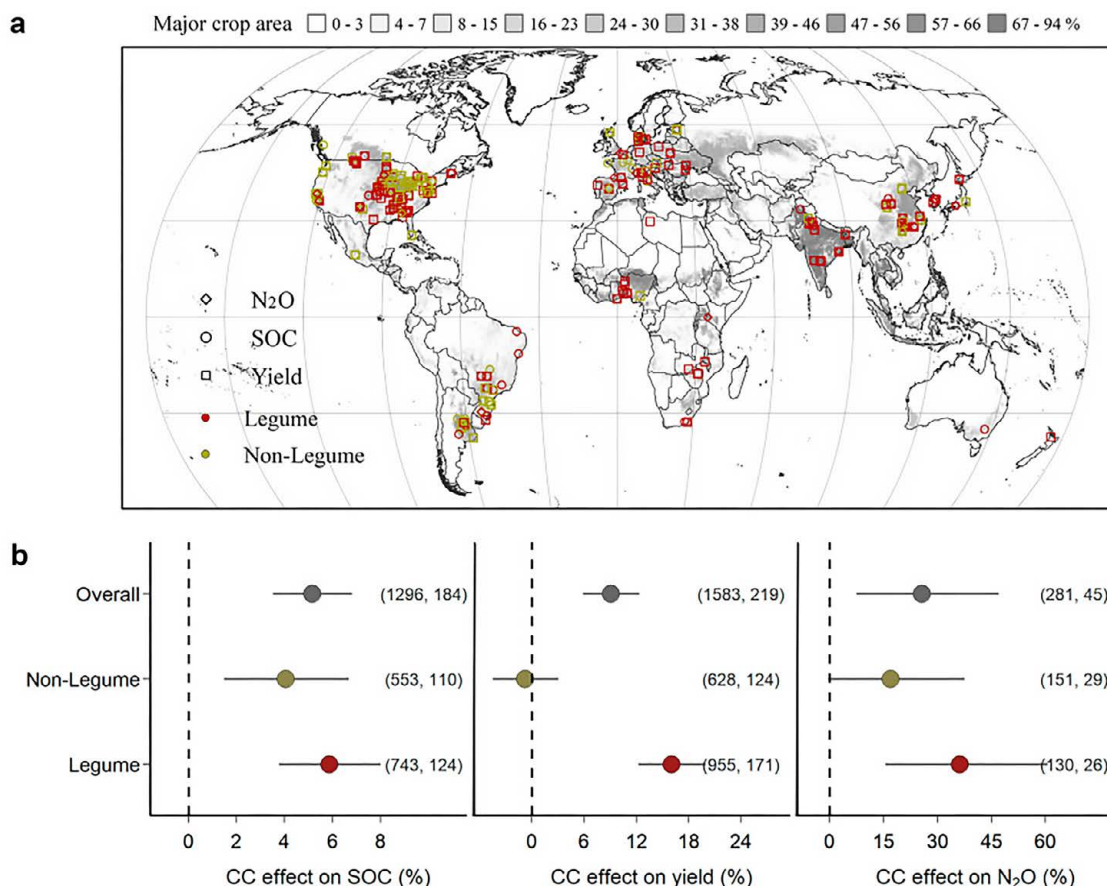
More than 75 per cent of subsistence farmers in rural Timor-Leste face challenges from unsustainable land use practices, particularly slash-and-burn farming on degraded steep slopes. These practices contribute to soil erosion, and poor crop yields, ultimately leading to land and environmental degradation and food insecurity. Recently, agroforestry projects have aimed to improve land productivity and farmers' livelihoods, though their impact remains unclear. This study aimed to evaluate these impacts through three research questions:

1. How do agroforestry interventions impact field crop performance and smallholder farmers' livelihoods?
2. What is the extent of farmer adoption of these interventions?
3. What is the effect of agroforestry interventions on soil physical and chemical characteristics?

The study was conducted at the Global Climate Change Alliance (GCCA) project site at Saraida, Quelicai, Baucau municipality, during the rainy season from December 2021 to April 2022. Interviews and focus group discussions were conducted with 35 farmers involved in the project, alongside field assessments of soil erosion and pot experiments. The results showed that most farmers reported improved production and outcomes from growing trees and would like to replicate agroforestry systems, suggesting adoption likelihood due to the multiple benefits of agroforestry, including soil improvement, animal feed, fuelwood provision, and environmental and biodiversity sustainability.

Measurements of soil loss and plant productivity confirmed the positive impact of agroforestry, reducing soil erosion by nearly 15 times compared to traditional fallow systems and improving crop growth and yields in both fallow and slash-and-mulch systems. This study provides essential baseline data and guidance for future farmland management in Timor-Leste.

This research is supported by the ACIAR Alumni Research Support Facility (ARSF2) project (Grant numbers C002084-018).



Site distribution and overall cover crop effects. (a) World map showing the locations of the 271 primary studies included in this study. (b) Overall effects of legume and non-legume cover crops (CCs) on SOC, yield, and N₂O emissions compared to no cover crop. Numbers in parentheses are observations in each grouping, followed by the number of corresponding unique sites. Center dots indicate mean effect sizes, and error bars indicate 95 per cent confidence intervals.

Optimising cover cropping application for sustainable crop production

Project team: Associate Professor Chaoqun Lu⁴ (project leader; clu@iastate.edu), Dr Linchao Li^{2,4}, Dr Qinsi He^{2,3,4}, Dr Annette Cowie^{5,6}, Dr Shuaixiang Zao⁷, Dr Li Liu^{5,8}, Dr Bo Yi⁴, Dr Lijie Shi⁹, Dr Shengwei Zhang^{2,10,11}, Dr Tianyi Qiu¹², Dr Yu Shi⁷, Dr Alfredo Huete³, Hackett Professor Kadambot Siddique¹, Dr Qiang Yu¹³

Collaborating organisations: ¹UWA;

²Inner Mongolia Agricultural University, China; ³University of Technology Sydney; ⁴Iowa State University, USA; ⁵NSW DPIRD; ⁶University of New England; ⁷Peking University, China; ⁸University of New South Wales; ⁹Yangzhou University, China; ¹⁰Inner Mongolia Key Laboratory of Ecohydrology and High Efficient Utilisation of Water Resources, China; ¹¹Autonomous Region Collaborative Innovation Center for Integrated Management of Water Resources and Water Environment in the Inner Mongolia Reaches of the Yellow River, China; ¹²Wuhan University of Technology, China; ¹³Northwest A&F University, China

Cover cropping is a key strategy in sustainable agriculture but faces adoption barriers due to perceived yield risks and uncertain environmental benefits. Through a global meta-analysis of 3160 observations from 271 studies, this project assessed the impacts of cover crops on soil organic carbon (SOC), crop yield, and nitrous oxide (N₂O) emissions.

Results showed that legume and non-legume cover crops increased SOC by 5.9 and 4.0 per cent, respectively. Legume cover crops enhanced yield by 16.0 per cent but raised N₂O emissions by 36.2 per cent, which can be mitigated by integrating practices like no-tillage, deficit irrigation, and diversified crop rotations.

The greatest benefits in SOC and yield from legume cover crops were observed in farming systems with low nitrogen fertiliser, low crop diversity (especially cereal-dominated systems), and low initial SOC, under humid and warm climates. Incorporating legume cover crops brings co-benefits for both SOC and yield, but the trade-offs in N₂O emissions should be deliberated.

This research is supported by Fundamental Research Funds for the Inner Mongolia Universities-Science Foundation; Iowa Nutrient Research Center; National Natural Science Foundation of China; the Program for Innovative Research Team in Universities of Inner Mongolia Autonomous Region.

Evaluation of cotton planting suitability in Xinjiang based on climate change and soil fertility factors simulated by coupled machine learning model

Project team: Professor Yi Li^{2,3,4} (project leader; liyi@nwafu.edu.cn), Dr Yonglin Jia², Professor Asim Biswas⁵, Dr Jiayin Pang¹, Dr Xiaoyan Song², Dr Guang Yang³, Dr Zhen'an Hou³, Dr Honghai Luo³, Dr Xiangwen Xie⁴, Dr Javlonbek Ishchanov⁶, Dr Ji Chen⁷, Dr Juanli Ju², Hackett Professor Kadambot Siddique¹

Collaborating organisations: ¹UWA; ²Northwest A&F University, China; ³Shihezi University, China; ⁴Xinjiang Academy of Agricultural Sciences, China; ⁵University of Guelph, Canada; ⁶National Research University, Uzbekistan; ⁷The University of Hong Kong, China

Cotton is the world's most widely cultivated fibre crop and holds great significance in Xinjiang. However, unsuitable planting environments can hinder farmers' income and result in a substantial waste of agricultural resources. This study explores the suitability of cotton planting areas in Xinjiang to reduce agricultural inputs and pollution. The goal is to promote sustainable agricultural development by considering both climate change and soil fertility, factors often overlooked in previous research.

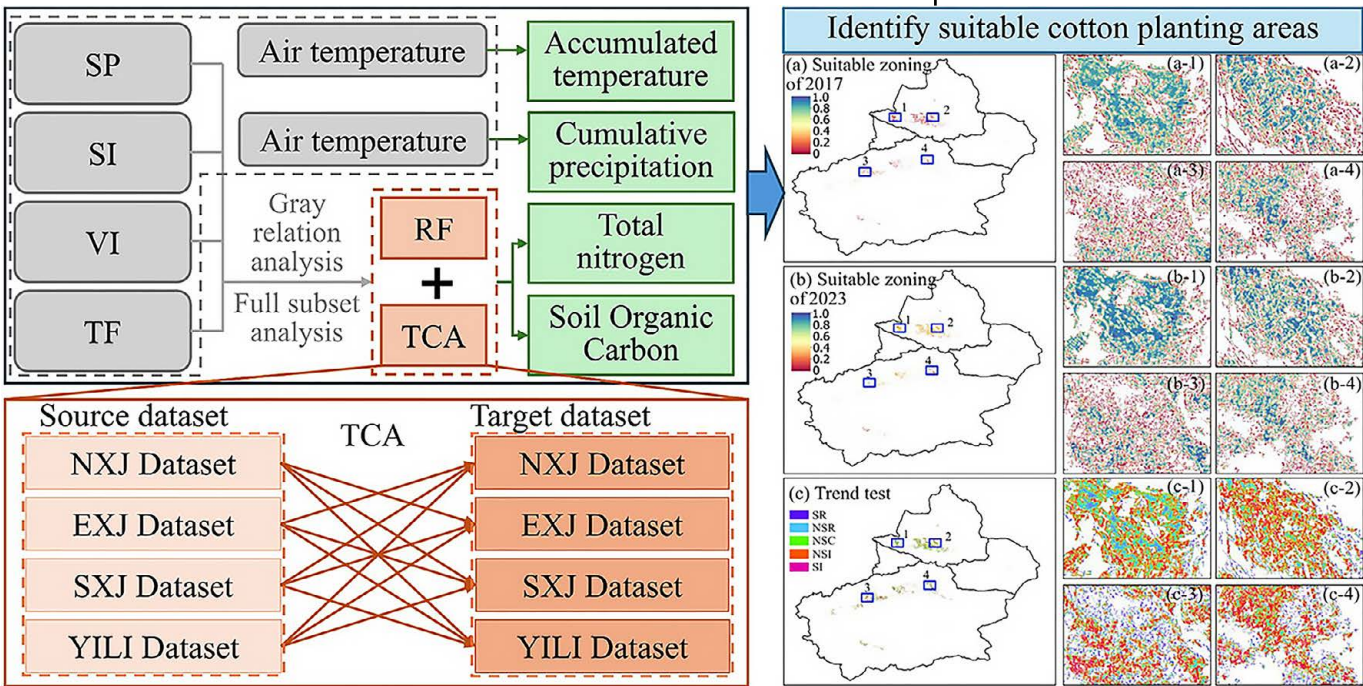
The climate change trends in Xinjiang were analysed, and machine learning-transfer component analysis was used to build a transferable coupling model for total nitrogen (TN) and soil organic carbon (SOC) indicators, resulting in a cotton suitability zoning that accounts for climate and soil fertility factors. Xinjiang has seen an overall increase in cumulative temperature and rainfall, with southern Xinjiang showing the most significant rise (4.02 per cent in temperature and 16.26 per cent in rainfall). The random forest model (RF) outperformed multivariate linear regression (MLR) and support vector machines (SVM) in predicting soil fertility indicators (TN: $R^2 = 0.80$, SOC: $R^2 = 0.77$). The RF-TCA coupling model enhanced adaptability, with better performance in TN prediction compared to SOC.

The Xinjiang cotton suitability zoning, based on meteorological and soil data, indicates a northward shift of suitable cotton-planting areas in northern Xinjiang. At the same time, southern Xinjiang continues to maintain a substantial number of suitable planting zones. Notably, the disparity in suitability between the two

regions has been narrowing over time. The research offers valuable insights for optimising cotton planting locations, enhancing resource efficiency, and promoting sustainable development in Xinjiang.

This research was jointly supported by the Key Research and Development Program of Xinjiang (No. 2022B02020-2), NYHXGG project (No. 2023AA303) and the High-end Foreign Experts Introduction Projects (No. s S20240082, H20240401 and S20240161).

Technical roadmap of this study. GEE: Google Earth Engine, AT: accumulated temperature, CP: cumulative precipitation, SOC: soil organic carbon, TN: total nitrogen, SP: soil parameters, SI: spectral index, VI: vegetation index, TF: texture feature, MLR: multi-variate linear regression, RF: random forest, SVM: support vector machine, TCA: transfer component analysis.



Enhancing carbon sequestration and greenhouse gas mitigation in semiarid farmland: The promising role of biochar application with biodegradable film mulching

Project team: Professor Peng Zhang² (project leader; pengzhang121@hotmail.com), Dr Jinwen Pang², Dr Zhonghong Tian², Dr Mengjie Zhang², Dr Yuhao Wang², Dr Tianxiang Qi², Dr Qilin Zhang², Dr Enke Liu³, Dr Weijun Zhang⁴, Dr Xiaolong Ren², Dr Zhikuan Jia², Hackett Professor Kadambot Siddique¹

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

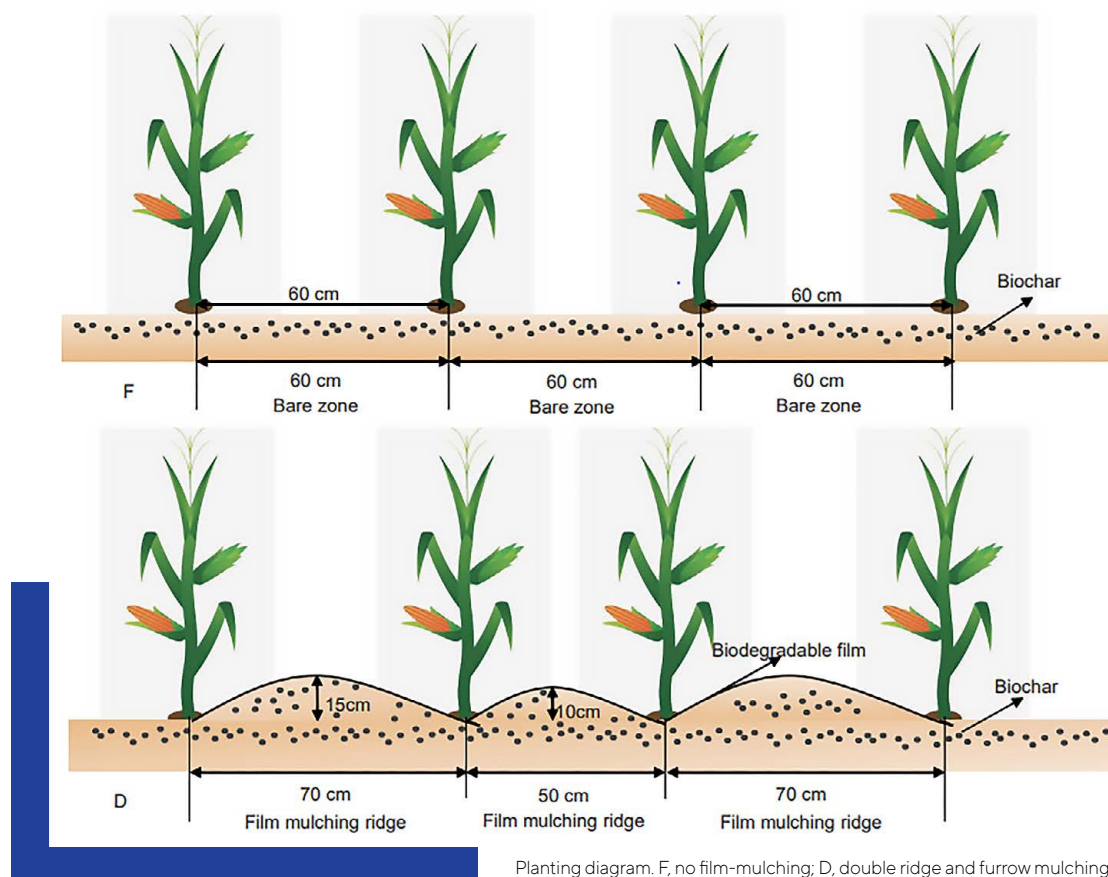
Long-term mulching has improved crop yields and farmland productivity in semiarid areas, but it has also increased greenhouse gas (GHG) emissions and depleted soil fertility. Biochar application has emerged as a promising solution for addressing these issues. This study investigated the effects of four biochar application rates (no biochar

(N)=0 t ha⁻¹, low (L)=3 t ha⁻¹, medium (M)=6 t ha⁻¹, and high (H)=9 t ha⁻¹) under film mulching and no mulching conditions over three growing seasons.

The impacts on GHG emissions were assessed along with soil organic carbon sequestration (SOCS), and maize yield to evaluate the productivity and sustainability of farmland ecosystems. The results demonstrated that mulching increased maize yield (18.68–41.80 per cent), total fixed C in straw (23.64 per cent), grain (28.87 per cent), and root (46.31 per cent) biomass, and GHG emissions (CO₂, 10.78 per cent; N₂O, 3.41 per cent), while reducing SOCS (6.57 per cent) and GHG intensity (GHGI; 13.61 per cent). Under mulching, biochar application significantly increased maize yield (10.20 per cent), total fixed C in straw (17.97 per cent), grain (17.69 per cent) and root (16.75 per cent) biomass, and SOCS (4.78 per cent).

Moreover, it reduced the GHG emissions (CO₂, 3.09 per cent; N₂O, 6.36 per cent) and GHGI (12.28 per cent). These effects correlated with the biochar addition rate, with the optimal rate being 9.0 t ha⁻¹. In conclusion, biochar application reduces CO₂ and N₂O emissions, enhances CH₄ absorption, and improves maize yield under film mulching. It also improves the soil carbon fixation capacity while mitigating the warming potential, making it a promising sustainable management method for mulched farmland in semiarid areas.

This research was supported by the National Key Research and Development Program of China (2021YFE0101300 and 2021YFD1901102), the Natural Science Basic Research Plan in Shaanxi Province, China, and the Ningxia Key Research and Development Program, China.



Planting diagram. F, no film-mulching; D, double ridge and furrow mulching (film mulching).



Winter wheat cultivar improvement affects rare bacterial communities in the rhizosphere more than abundant ones

Project team: Professor Xiaoliang Qin² (project leader; qinxiaoliang@nwsuaf.edu.cn), Dr Chunhong Xu², Dr Pengfei Dang², Dr Bart Haegeman³, Dr Tiantian Huang², Dr Xiaoqing Han², Dr Miaomiao Zhang², Dr Shiguang Wang², Hackett Professor Kadambot Siddique¹

Collaborating organisations: ¹UWA;

²Northwest A&F University, China;

³Sorbonne University, France

Understanding the impact of genetic improvements in wheat cultivars on microbial communities is crucial for enhancing nitrogen utilisation efficiency and increasing crop yields.

This study analysed 20 wheat cultivars released between 1964 and 2018, revealing shifts in abundant and rare bacterial communities in the rhizosphere, with distinct patterns over time. The α -diversity of abundant bacterial communities significantly declined with newer cultivars, while rare communities increased. The β -diversity of abundant groups remained stable, while rare groups decreased. Stochastic processes influenced these communities, with abundant groups maintaining a constant degree of stochasticity and rare groups experiencing greater stochasticity. Functional predictions revealed decreased anaerobic chemoheterotrophy and fermentation and increased ureolysis and aromatic compound degradation in rare communities.

Random forest analysis showed that the composition of the rare bacterial

communities explained more variation in cultivar improvement than that of abundant communities. In abundant bacterial communities, increases in *F. Rhizobiaceae* and *G. Pedobacter* correlated with higher grain yield and nitrogen utilisation efficiency. In rare bacterial communities, higher grain yields were associated with increases in *S. Pelomonas_aquatica*, *S. Dyadobacter_hamtensis*, *G. Erwinia*, and *G. Sphingobacterium*, while *P. Candidatus_Saccharibacteria* and *S. Dyadobacter_hamtensis* contributed to enhanced nitrogen efficiency. These findings offer valuable insights into how genetic improvements in wheat cultivars influence soil bacterial communities, potentially optimising nitrogen utilisation and boosting grain yields.

This research was supported by NNSFC (32272217).

Differential resilience of chickpea's reproductive organs to cold stress across developmental stages: insights into antioxidant strategies for enhanced fertility

Project team: Dr Harsh Nayyar² (project leader; harshnayyar.hn@gmail.com), Deeksha Padhiar², Sarbjeet Kaur², Dr Uday Chand Jha⁴, Professor PV Vara Prasad⁴, Professor Kamal Dev Sharma⁵, Professor Sanjeev Kumar⁶, Dr Swarup Kumar Parida⁷, Hackett Professor Kadamott Siddique¹

Collaborating organisations: ¹UWA; ²Panjab University, India; ³Indian Institute of Pulses Research; ⁴Kansas State University, USA; ⁵Chaudhary Sarwan Kumar Himachal Pradesh Agricultural University, India; ⁶Central University of Punjab, India; ⁷National Institute of Plant Genome Research, India

Chickpea is highly sensitive to cold stress during its reproductive stages, leading to significant reductions in potential pod formation due to decreased reproductive success. This study aimed to investigate the specific responses of anthers and ovules to cold stress, explore the role of oxidative stress and antioxidant mechanisms, and understand the relationship between oxidative stress and reproductive function to enhance our understanding of chickpea responses to cold stress.

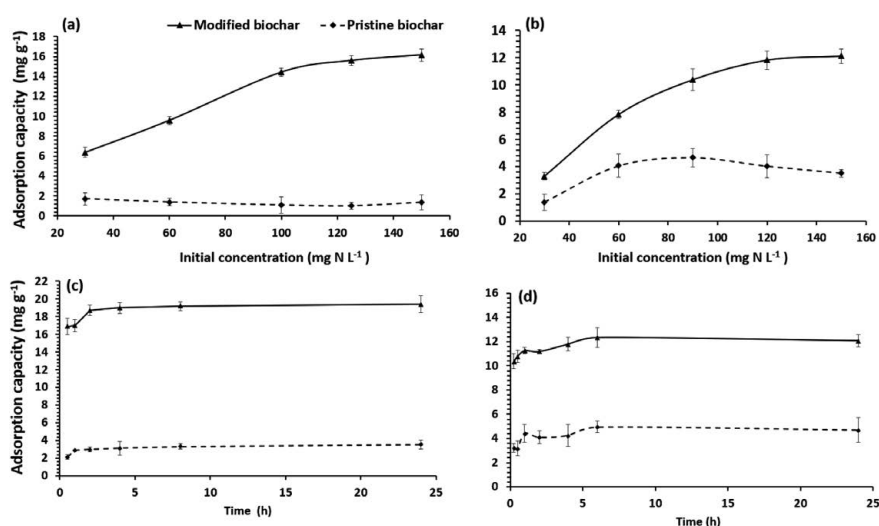
Chickpea seeds of contrasting genotypes—cold-tolerant (ICC 17258, ICC 16349) and cold-sensitive (ICC 15567, GPF 2)—were sown outdoors in early November under optimal conditions (25.5/15.4°C mean day/night temperatures). At 50 days after sowing, plants were subjected to 13/7°C cold stress (12 h light/dark in walk-in growth chambers). Cold stress significantly increased membrane damage and reduced cellular viability in anthers and ovules, particularly in cold-sensitive (CS) genotypes. Oxidative damage was more pronounced in anthers, particularly at anthesis (stage 2), as indicated by elevated malondialdehyde and hydrogen peroxide levels. Cold-tolerant (CT) genotypes exhibited increased antioxidant activity under stress, especially at pre-anthesis (stage 1), followed by declines at later stage, although responses varied by genotype. Anthers exhibited higher overall antioxidants activity than ovules, while ovules demonstrated notably high catalase activity.

Among the antioxidants studied, ascorbate peroxidase and glutathione reductase were most prominent in the CT genotype, along with higher levels of ascorbate (AsA) and glutathione (GSH), highlighting the critical role of the AsA-GSH cycle in conferring cold tolerance to chickpea. Exogenous supplementation with 1 mM AsA and GSH significantly stimulated pollen germination in cold-stressed plants under *in vitro* conditions, with a greater effect observed in CS genotypes. Furthermore, antioxidant activity strongly correlated with key reproductive traits such as pollen germination and ovule viability. This study revealed that the anthers and ovules exhibited distinct responses to cold stress, with significant genotypic differences across key reproductive stages. These insights provide a deeper understanding of cold tolerance mechanisms in chickpea and provide vital clues for breeding strategies to enhance resilience and reproductive success under cold stress.

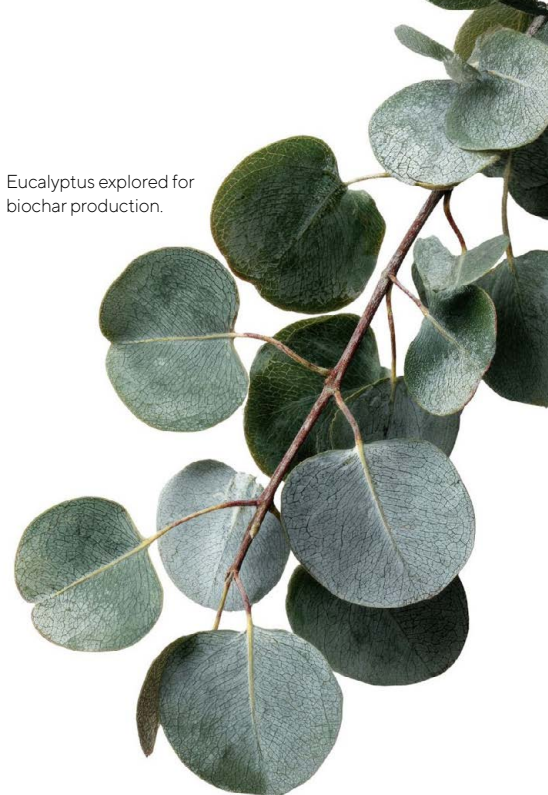
This research is supported by The Department of Biotechnology, New Delhi.



A collection of chickpea seeds.



Eucalyptus explored for biochar production.



Effect of initial ammonium concentrations (a, b) and contact times (c, d) on the adsorption capacity (q_e) of pristine and modified eucalypt biochar in ammonium from pure ammonium solution (100 mg N L^{-1} , biochar rate 3 g L^{-1}) (a, c) and anaerobic digestate (100 mg N L^{-1} , biochar rate 3 g L^{-1}) (b, d). In all cases, pH was 7, and the temperature was 25°C . Means $\pm$ SE ($n=4$).

Adsorption of ammonium from anaerobic food waste digestate by pristine and modified eucalyptus biochar for nitrogen fertiliser use

Project team: Associate Professor Zakaria M. Solaiman¹ (project leader; zakaria.solaiman@uwa.edu.au), Dr Hend A. Mohamed¹, Professor Zed Rengel¹, Professor Nanthi Bolan¹, Dr Basit Ahmed Khan², Hackett Professor Kadambot Siddique¹

Collaborating organisations: ¹UWA; ²Quaid-i-Azam University, Pakistan

Australia generates approximately 14.4 million tonnes of organic waste annually, encompassing food, garden, timber and agricultural waste, with about half of this waste (6.7 million tonnes) ending up in landfills. Finding a sustainable strategy to deal with enormous amounts of organic waste is a global challenge. Effectively managing and transforming organic waste into a valuable resource is critical for minimising environmental impact, conserving resources, and mitigating climate change.

When properly implemented, anaerobic digestion can stabilise solid waste with high organic matter content, offering environmental, economic, and energy-related benefits. This process plays a crucial role in sustainable waste management practices, contributing to the circular economy by converting waste, such as

food scraps, garden waste and other biodegradable materials into valuable resources. Anaerobic digestate of solid food waste has high ammonium (NH_4^+) concentration and discharging it into the environment after nitrification may cause eutrophication. This study aimed to characterise (i) the adsorption of NH_4^+ from anaerobic digestate of food waste by biochar derived from mixed eucalypt (*Eucalyptus* spp.) tree species before and after modification with HNO_3 and Na_2CO_3 and (ii) the use of NH_4^+ -loaded biochar as a potential N fertiliser.

The isotherm and kinetics experiments using pure NH_4^+ solution and anaerobic digestate solution revealed that modifications to eucalypt biochar enhanced NH_4^+ adsorption capacity, predominantly through ion exchange and electrostatic interaction related to cation exchange capacity. A glasshouse pot study using maize plants was conducted with ammonium-loaded pristine and modified eucalypt biochar. The batch sorption data were fitted to Langmuir and Freundlich models for the isotherm and pseudo-first order, pseudo-second order, Elovich, and intraparticle diffusion models for the kinetics. The pseudo-second order and Elovich models closely matched the experimental breakthrough curves

for NH_4^+ . Post-modification, the eucalypt biochar effectively extracted NH_4^+ from pure NH_4^+ solution and digestate, primarily through chemisorption via ion exchange, electrostatic interaction, cationic interaction.

A glasshouse pot study using maize plants revealed that ammonium-loaded pristine and modified eucalypt biochar increased plant growth, suggesting that it can be used as an alternative to synthetic N fertiliser. Modified eucalypt biochar might be suitable for treating digestate liquid from various sources and reducing NH_4^+ concentration and N losses from digestate liquid. Enriched modified biochar might be reused as nitrogen fertiliser in the soil. Future research is required to study how modifications affect biochar properties for increasing nutrient-loading techniques. A deeper understanding of targeted modifications and optimisation strategies is essential to improve biochar's ability to retain and release specific nutrients, adapt to different soil conditions, and support various crop types.

This research is supported by UWA, CAUL, and its Member Institutions.

Phenotypic advantages and improved genomic stability following selection in advanced self-generations of *Brassica* allohexaploids

Project team: Dr Sheng Chen¹ (project leader; sheng.chen@uwa.edu.au), Dr Yan Niu², Rui Yang², Zelong Li², Zhengxuan Huo², Shihao Chang², Entang Tian^{2,3}, Han Qin², Professor Wallace A Cowling¹, Hackett Professor Kadambot Siddique¹, Professor Annaliese S Mason⁴, Professor Jun Zou²

Collaborating organisations: ¹UWA; ²Huazhong Agricultural University, China; ³Guizhou University, China; ⁴University of Bonn, Germany

Numerous allopolyploid species, containing two or more genomes from different species origins, exist in nature. Many of these allopolyploids have been successfully domesticated and are now major crops, such as bread wheat, coffee, oats, rapeseed/canola, and cotton. Allopolyploids often exhibit advantages in vigor and adaptability compared to diploids. A long-term goal in the economically important *Brassica* genus has been to develop a new allohexaploid crop type (AABBCC) by combining different diploid and allotetraploid crop species. However, early-generation allohexaploids often face challenges like unstable meiosis and low fertility, and the phenotypic performance of these synthetic lines has rarely been assessed. This study analyses agronomic traits, fertility, and genome stability in A¹A¹B¹B¹C¹C¹ lines derived from four crosses between *Brassica carinata* and *B. rapa* after 9-11 selfing generations.

In the current study, plants with high pollen fertility were selected, and plants with 54 chromosomes from four hybrid combinations (C13, C21, C28, and C34) were identified as exhibiting the highest fertility and the highest percentage of plants with 54 chromosomes over successive generations of selfing and selection. This process resulted in H11 hexaploids for the C13 and C28 combinations, and generation H9 hexaploids for the C21 and C34 combinations. The results demonstrate polyploid advantage in vigor and seed traits, considerable phenotypic variation, and high fertility and genome stability.

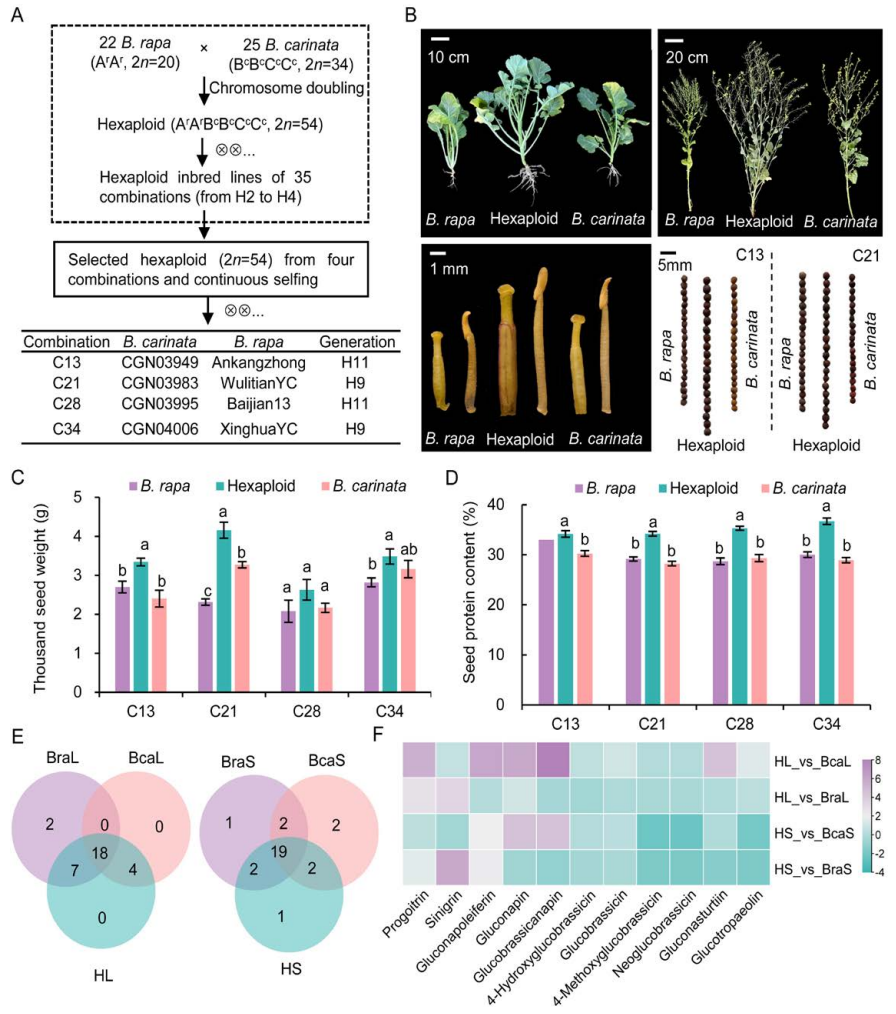
Meanwhile, parental genotypes significantly influence outcomes in advanced allohexaploids. Structural variants, largely

resulting from A-C homoeologous exchanges, contribute to genomic variation and influence hexaploid genome stability, with the A sub-genome showing the highest variability. Both positive and negative impacts of SVs on fertility and seed weight are observed. Pseudo-euploids, frequently appearing, do not significantly affect fertility or other agronomic traits compared to euploids, indicating a potential pathway toward a stable allohexaploid species. These findings provide

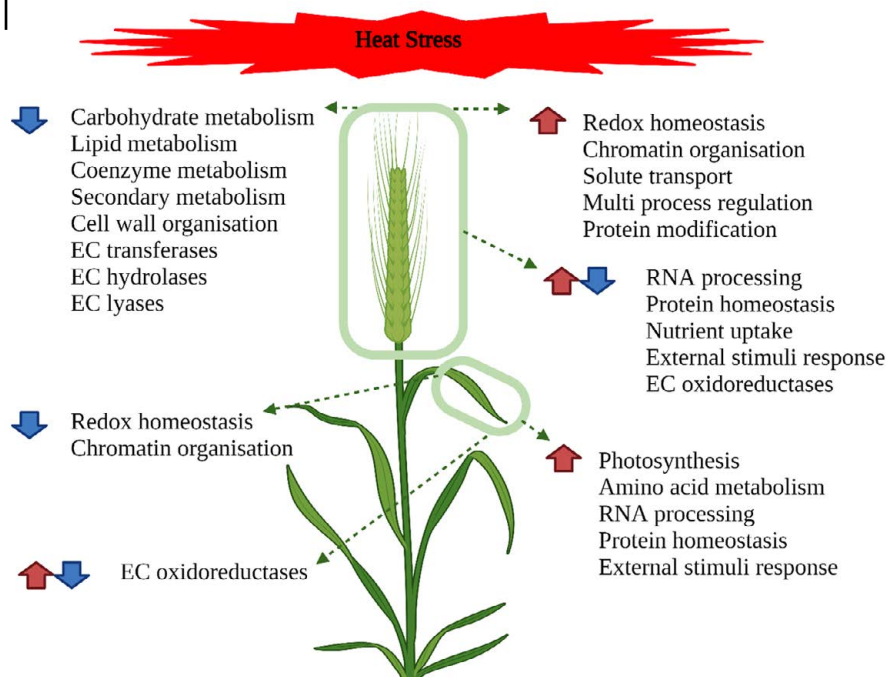
insights into the challenge and potential for developing an adaptable and stable *Brassica* hexaploid through targeted selection and advanced genomic technologies.

This research is supported by the Sino-German Research Project (GZ1362), GRDC International Visiting Fellowship (UWA2406-010BGX), NNSFC (32171982), and the Fundamental Research Funds for the Central Universities of the Chinese Government (2662023PY004).

Development and polyploid advantages of advanced-generation inbred hexaploid *Brassica* lines of A¹A¹B¹B¹C¹C¹ over diploid parents across four *B. rapa* × *B. carinata* crosses. **A:** Hexaploid populations developed from previous *B. rapa* and *B. carinata* crosses (Tian et al., 2010). **B:** Images of representative inbred hexaploid progeny and diploid parents showing seedling vigour, inflorescences, stigmas and anthers, and seeds (20 seeds per column) **C** and **D:** Mean thousand-seed weight (C) and mean seed protein content (D) of 300 hexaploid progenies (H9-H11) compared to diploid parents in 2021; significance testing was conducted using ANOVA/Student's t-test. **E** and **F:** Distribution patterns of glucosinolate types (E) and content differences, based on log₂(FoldChange) values (F), in the hexaploid. HL, HS, BraL, BraS, BcaL, and BcaS represent the glucosinolates in hexaploid leaves, hexaploid seeds, *B. rapa* leaves, *B. rapa* seeds, *B. carinata* leaves, and *B. carinata* seeds, respectively.



Graphical abstract describing proteomic responses in wheat.



Unravelling heat tolerance in bread wheat

Project team: Hackett Professor Kadambot Siddique¹ (project leader; kadambot.siddique@uwa.edu.au), Associate Professor Nicolas Taylor¹, Dr Agyeya Pratap¹

Collaborating organisation: ¹UWA

Rising temperatures and more frequent heatwaves pose a major threat to global wheat production, particularly when heat stress coincides with flowering and grain-filling stages. This project investigated the physiological and molecular mechanisms underpinning heat tolerance in bread wheat (*Triticum aestivum* L.) to identify traits and protein biomarkers that can inform the breeding of climate-resilient wheat varieties.

Controlled-environment experiments were conducted in India and Australia using wheat genotypes with contrasting heat tolerance. Plants were exposed to short-term and long-term heat stress regimes (32°C) during the critical “ear peep” stage of development, as well as at the seedling stage. Detailed measurements of plant physiology, phenology, yield components, and grain quality were integrated with advanced proteomics analyses of flag leaf and spike tissues. Heat stress significantly reduced grain yield across all genotypes, primarily through losses in grain number under short-term heat exposure and

reduced grain weight under prolonged heat stress. However, heat-tolerant genotypes consistently outperformed susceptible ones. They maintained higher photosynthetic capacity, pollen viability, chlorophyll content, membrane stability, and above-ground biomass while limiting oxidative damage. These traits were strongly associated with yield retention and harvest index under heat stress, highlighting their importance for breeding resilient wheat.

Proteomic analyses revealed distinct molecular responses between tolerant and susceptible genotypes. Heat-tolerant wheat showed increased abundance of proteins involved in photosynthesis, amino acid metabolism, protein stability, and chromatin organisation, particularly in flag leaves. In contrast, heat-susceptible genotypes exhibited disrupted redox homeostasis and reductions in proteins associated with carbohydrate metabolism, cell wall structure, and energy regulation, especially in spike tissues. Network and correlation analyses linked specific protein groups, particularly those involved in redox balance and chlorophyll biosynthesis, to grain yield and grain number, indicating their potential as predictive markers of heat tolerance.

To translate these findings into practical tools for crop improvement, a targeted proteomics approach (selected reaction monitoring mass spectrometry) was used to validate candidate protein biomarkers at both seedling and reproductive stages. Key proteins, including Rubisco activase and a DM2 domain-containing protein, showed strong, consistent associations with physiological performance and yield under heat stress across developmental stages. Overall, this research provides an integrated physiological and molecular framework for understanding heat tolerance in wheat. By identifying robust biomarkers associated with yield stability under heat stress, the project provides tangible targets for breeding programs. It contributes to efforts to safeguard wheat production and food security in a warming climate.

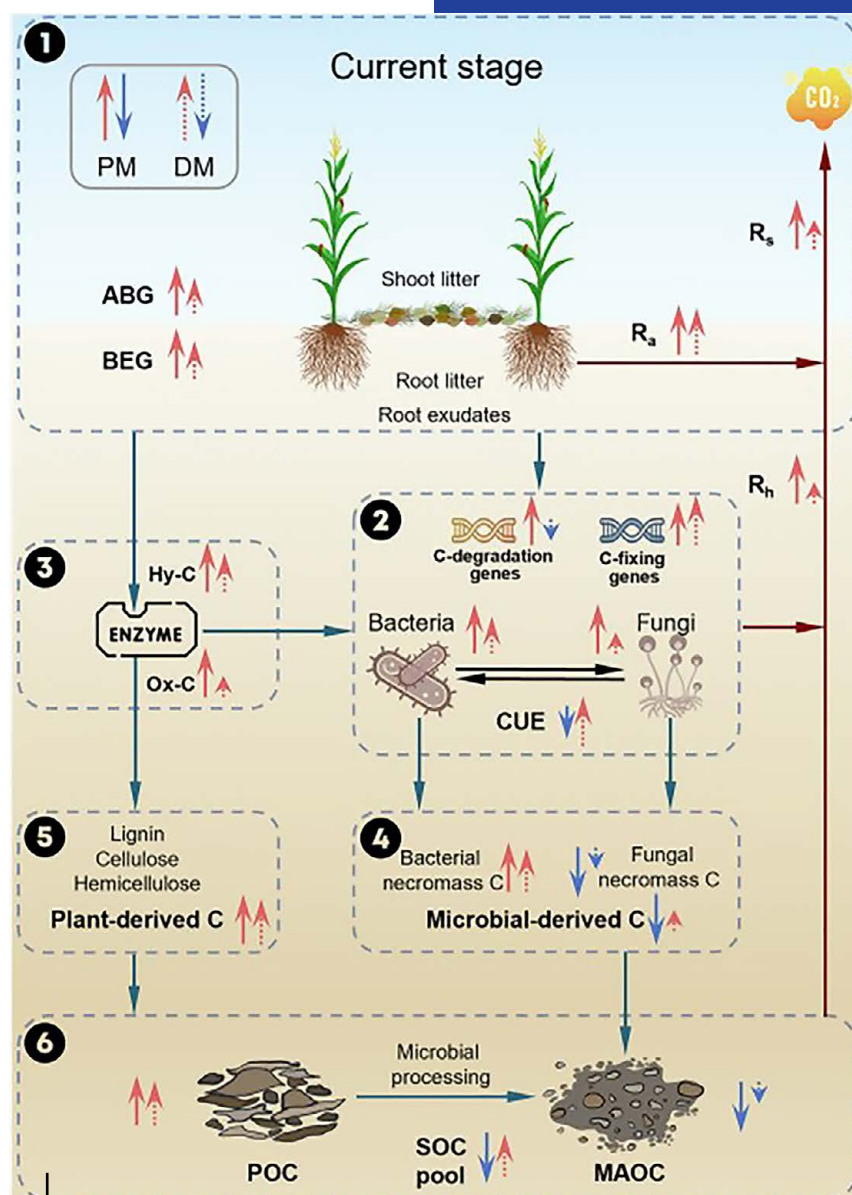
This research is supported by UWA and ICAR, India.

Degradable film mulching increases soil carbon sequestration in major Chinese dryland agroecosystems

Project team: Professor Yi Cheng^{15,17,18} (project leader; ycheng@njnu.edu.cn), Dr Zihan Liu¹⁷, Dr Chenxu Zhao², Dr Nanhai Zhang², Dr Jing Wang³, Dr Zhaoyang Li², Dr Yves Uwiragiye¹⁷, Dr Nyumah Fallah¹⁷, Dr Thomas W Crowther⁴, Dr Yuanyuan Huang^{5,6}, Dr Yuanyuan Huang⁷, Dr Yi Xu^{8,9}, Dr Sheng Zhang⁷, Dr Yakov Kuzyakov^{10,11}, Hackett Professor Kadambot Siddique¹, Dr Zhikuan Jia², Dr Zucong Cai¹⁷, Dr Scott X Chang¹², Dr Minggang Xu^{13,14}, Dr Christoph Müller^{15,16}

Collaborating organisations: ¹UWA; ²Northwest A&F University, China; ³Nanjing Forestry University, China; ⁴Institute of Integrative Biology, Switzerland; ⁵German Centre of Integrative Biodiversity Research Halle-Jena-Leipzig, Germany; ⁶Leipzig University, Germany; ⁷Chinese Academy of Sciences, China; ⁸China Agricultural University, China; ⁹University of Tübingen, Germany; ¹⁰University of Göttingen, Germany; ¹¹Peoples Friendship University of Russia, Russia; ¹²University of Alberta, Canada; ¹³Shanxi Agricultural University, China; ¹⁴Chinese Academy of Agricultural Sciences, China; ¹⁵Justus Liebig University Giessen, Germany; ¹⁶University College Dublin, Ireland; ¹⁷Nanjing Normal University, China; ¹⁸Jiangsu Center for Collaborative Innovation in Geographical Information Resource Development and Application, China

Plastic film mulching (PM), which contributes to nearly half of the increased crop yields in dryland agroecosystems, exacerbates environmental burdens due to its non-degradable nature. Globally, there is a growing demand to replace non-degradable PM with degradable film mulching (DM), yet its impacts on soil organic carbon (SOC) in dryland



Conceptual framework illustrating mechanisms that control SOC sequestration under film mulching practices: (1) Film mulching alters crop productivity and biomass allocation to subsequently influence soil C inputs. (2) Pathway for microbial in vivo turnover. (3) Pathway for microbial ex vivo modification. (4) Accumulation of microbial-derived C. (5) Accumulation of plant-derived C. (6) Changes in SOC, POC, and MAOC.

agroecosystems remains unknown. Drawing on multi-site fieldwork and mesocosm experiments across China, this study addressed a knowledge gap in the global push to transition away from traditional plastic mulching. By identifying the microbial pathways involved, the study improved understanding of how soil carbon cycles respond to different land management practices.

The results showed that DM strongly increased but PM reduced SOC storage (0–1 m). This difference is likely attributable to the higher microbial C use efficiency in soil under DM, leading to increased microbial-derived C compared to PM. Under the high roading scenario for 2100, DM could reduce the decomposition of

SOC (0–1 m) in China's drylands by $9.0 \pm 1.0 \text{ Mg ha}^{-1} \text{ year}^{-1}$ (one standard error) compared with PM. Our findings highlight that DM is a promising alternative to PM for sequestering SOC and alleviating C loss under climate change in dryland agroecosystems.

This research is supported by NNSFC (Nos. 42425705, U23A2052, and 42407421), China 111 Project (No. B12007), and the National Key Research and Development Program of China (No. 2021YFE0101302).

Proteomic analysis reveals differentially abundant proteins involved in post-pollination responses to heat stress in *Brassica napus*

Project team: Professor Wallace Cowling¹ (project leader; wallace.cowling@uwa.edu.au), Dr Xiaojie Hu¹, Dr Sheng Chen¹, Dr Xiaoke Ping^{1,2}, Hackett Professor Kadambot Siddique¹

Collaborating organisations: ¹UWA; ²Southwest University, China

Heat stress significantly reduces *Brassica napus* (canola/oilseed rape) seed production during the post-pollination stages. This study explored changes in the proteome of flowers on the main stem of three *B. napus* cultivars exposed to transient heat stress after pollination. Flowers at the 2nd to 5th reproductive nodes on the main stem were collected on days 0, 1, 3 and 6 of heat stress and control treatments. The three cultivars, Alku, AV-Ruby, and YM11, exhibited varying degrees of heat sensitivity and resilience based on seed production in pods at these reproductive nodes. The seed yield per pod under heat stress was 75.3 per cent of the

control in Alku and 64.2 per cent in YM11. However, AV-Ruby retained 93.5 per cent of its seed yield under heat stress, from which we conclude AV-Ruby was more resilient to heat stress during the post-pollination stage than Alku or YM11. There were 474 differentially abundant proteins (DAPs) identified across all cultivars and time points. Among the DAPs, two HSP20-like chaperones (AOA078I8F7, AOA078JBL3) and one HSP related protein (AOA078JJT8) were consistently highly abundant under heat and were strong candidates as heat responsive proteins. Pathways related to maintaining membrane integrity were specifically enriched in AV-Ruby, and deserve further study for their potential involvement in heat tolerance.

Heat stress is a major factor threatening seed yield in cool season crops including oilseed rape, particularly during the post-pollination stages when pollination, fertilisation, and embryo development are

highly vulnerable to elevated temperatures. A comparative proteomic analysis was carried out to identify heat-responsive proteins during the post-pollination period. Among the DAPs, three were consistently associated with heat stress response. A range of biological processes, including protein folding and stress signalling, were involved in a general response to heat stress in all cultivars. Furthermore, pathways related to maintaining membrane integrity were specifically enhanced in a heat-resilient cultivar. These findings provide new insights into the heat response at the protein level and lay the groundwork for identifying potential molecular targets for breeding heat-tolerant oilseed rape cultivars.

This research from the PhD thesis of Dr Xiaojie Hu at UWA was published in *Journal of Proteomics* (2025) 319 : 105481

This research is supported by GRDC (UWA2404-011RTX) and UWA.



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



Control

Heat

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.



(L-R) Professor Wallace Cowling, Xiaoke Ping and Dr Xiaojie Hu celebrate the completion of her PhD.

Traditional rice varieties, consumer segmentation, and preferences: A case study from Kerala, India

Project team: Dr Jayasree Krishnankutty² (project leader; jayasree.krishna@kau.in), Dr Lakshmi Pottekkat Sasidharan², Rajesh K. Raju³, Dr Nadhika Kaladharan², Atheena UI Purath², Vivek Sugathan⁴, Professor Michael Blakeney¹, Hackett Professor Kadambot Siddique¹

Collaborating organisations: ¹UWA; ²Kerala Agricultural University, India; ³Department of Economics and Statistics, India; ⁴Department of Agriculture and Farmers Welfare, India

Traditional rice varieties (TRVs), which have been shaped by long-term adaptation to local soils and climates, are often considered less competitive than modern rice varieties (MRVs) due to their lower yields. Consequently, a global decline in TRV cultivation has been driven by the widespread adoption of MRVs. However, important advantages in nutritional quality, sensory attributes, and broader sustainability outcomes may be offered by TRVs. In this study, the nutritional characteristics and consumer preferences of selected TRVs and MRVs cultivated in Kerala, India were compared.

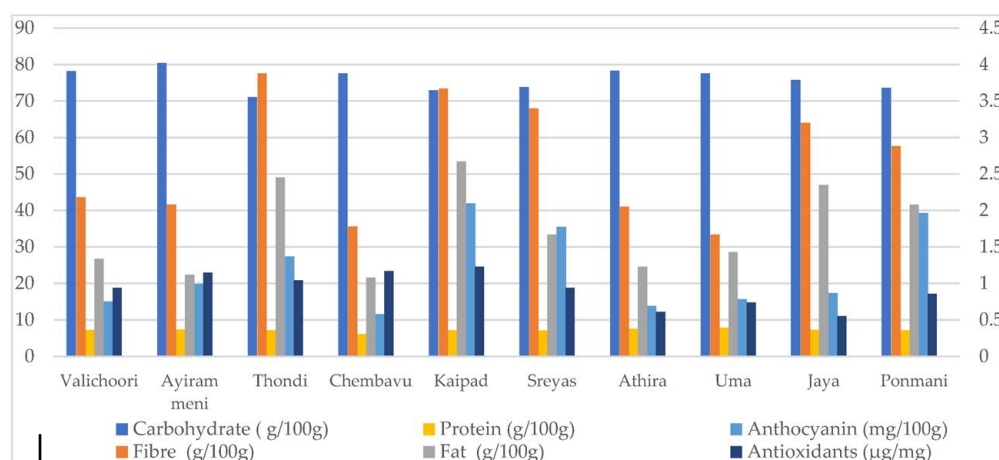
Physicochemical properties and sensory attributes of cooked rice were assessed, and consumer preference was analysed using Kendall's W test and multiple linear regression. In addition, consumer purchasing behaviour across different groups was evaluated through exit surveys conducted in supermarkets, which were analysed using cluster and discriminant function approaches.

Higher antioxidant and fibre contents were generally exhibited by TRVs, whereas significantly higher protein levels were found in MRVs. Overall, no consistent evidence of universal nutritional superiority between the two groups was observed, given the variation recorded across traits and varieties. However, TRVs were consistently favoured in sensory evaluation, with grain appearance and taste identified as key drivers of preference. These sensory attributes were also identified as the strongest predictors of overall consumer acceptance in statistical models.

A higher preference for TRVs was also indicated by consumer survey results, including greater willingness to purchase and pay premium prices among both younger consumers and older semi-urban residents. Significant contributions to consumer decision-making were also made by physicochemical characteristics, including carbohydrate, fibre, fat, protein, and mineral composition, although sensory traits remained the dominant influence.

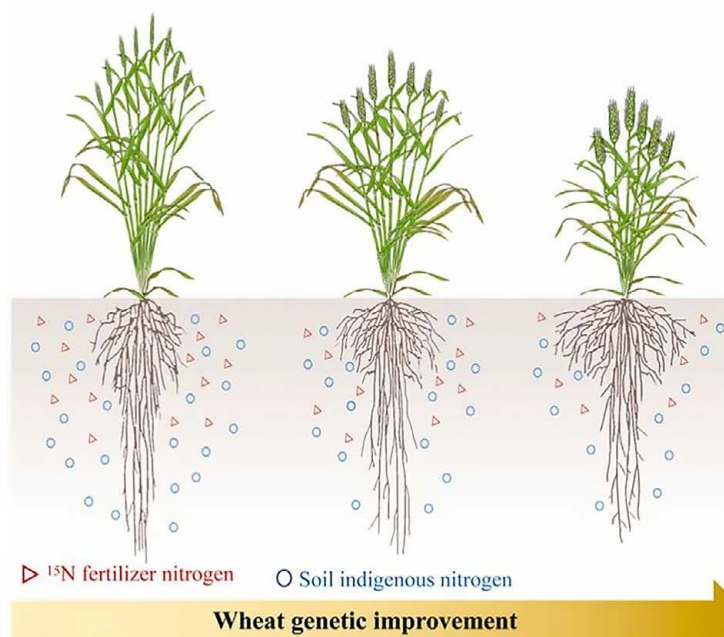
Overall, the findings suggest that although TRVs are not consistently superior to MRVs in all nutritional aspects, clear advantages are demonstrated in sensory quality and consumer appeal. The importance of promoting TRVs with strong taste and appearance attributes is therefore highlighted to support market demand and on-farm conservation.

This research is supported by the ARC Discovery Project (DP170100747) through UWA.

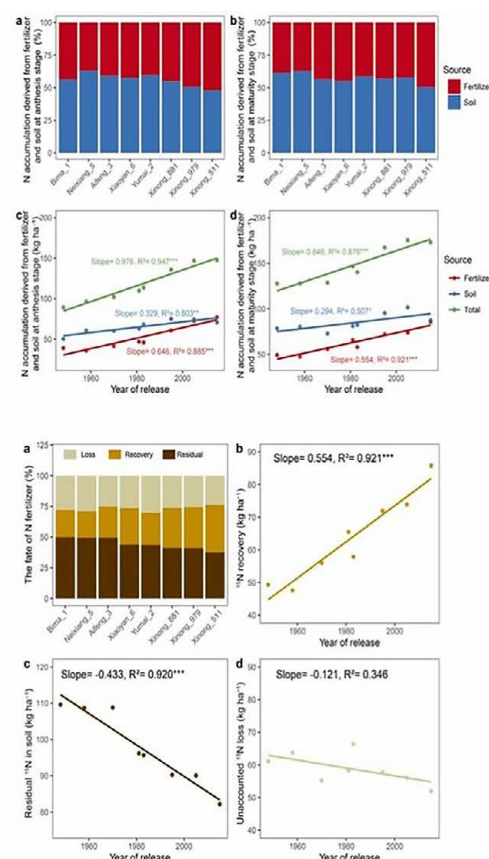


Distribution of selected physicochemical and nutritional attributes in traditional and modern rice varieties.

A selection of rice varieties.



Graphical abstract of the research project.



Wheat genetic improvement affects the fate of ^{15}N fertiliser, improving nitrogen uptake and utilisation

Project team: Professor Xiaoliang Qin² (project leader; xiaoliangqin2006@163.com), Dr Tiantian Huang², Dr Zhuanzhuan Zhang², Dr Ruiqi Sun², Dr Qianxiang Wu², Dr Xiaoru Zhao², Dr Xiaoli Zhong², Hackett Professor Kadambot Siddique¹

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

Excessive fertilisation increases production costs and contributes to environmental pollution, threatening agricultural sustainability. The efficiency with which wheat accumulates fertiliser nitrogen (N) directly affects economic returns and overall nitrogen use efficiency (NUE). Genetic improvement is a key strategy for enhancing NUE in wheat.

This study examined eight widely cultivated wheat varieties released between 1948 and 2015 in the Huang-HuaiHai region, using ^{15}N stable isotopes to assess N uptake and utilisation from fertiliser and soil indigenous N sources.

Genetic improvement has significantly enhanced wheat NUE, primarily by increasing N accumulation and transport capacity. Notably, wheat breeding has led to higher pre-anthesis N accumulation, while post-anthesis N accumulation has remained largely unchanged. Modern wheat varieties exhibit greater absorption of both fertiliser N and soil indigenous N. Additionally, the proportion of fertiliser-derived ^{15}N retained in wheat has increased, with a strong positive correlation observed between the ^{15}N uptake and root traits such as root length, weight, and surface area in the topsoil (0–20 cm). Genetic advancements have also improved post-anthesis N translocation, leading to higher translocation rates and a greater contribution of N to grain formation. Both fertiliser and soil indigenous N translocation increased as the variety release year progressed. At the end of the growing season, 21.5–28.8 per cent of fertiliser N was absorbed, with 35.4–49.8 per cent

remaining in the soil and 25.6–30.6 per cent lost through leaching. Genetic improvement has enhanced wheat's capacity to absorb fertiliser-derived ^{15}N , increasing ^{15}N nitrogen recovery efficiency and reducing the amount of residual ^{15}N fertiliser in the soil, with no significant change in ^{15}N fertiliser nitrogen loss.

These findings support the development of climate-smart, sustainable agricultural systems by integrating genetic improvement and refined N management strategies. Future wheat breeding programs should prioritise root system optimisation to enhance fertiliser N uptake and minimise residual soil N.

This research is supported by NNSFC (No. 32272217).

Influence of elevated temperature on the nutritional profile of Chickpea (*Cicer arietinum* L.) Seeds

Project team: Uday Chand Jha^{2,3} (project leader; u9811981@gmail.com), Dr Marilyn Warburton⁴, Professor Harsh Nayyar⁵, Dr Sadiya Shafi³, Professor Ignacio A Ciampitti^{3,6}, Dr Ashis Ranjan Udgata², Hackett Professor Kadambot Siddique¹, Professor P V Vara Prasad³

Collaborating organisations: ¹UWA; ²Indian Council for Agricultural Research, India; ³Kansas State University, USA; ⁴United States Department of Agriculture, USA; ⁵Punjab University, India; ⁶Purdue University, USA; ⁷National Agri-Food Biotechnology Institute, India

Increasing occurrences of episodic heat stress are significantly affecting crop quality traits, including those of chickpea (*Cicer arietinum* L.). To investigate the impact of elevated temperatures on seed nutritional quality, eight chickpea genotypes were grown under non-stress (25/15°C) and heat stress (35/20°C) conditions.

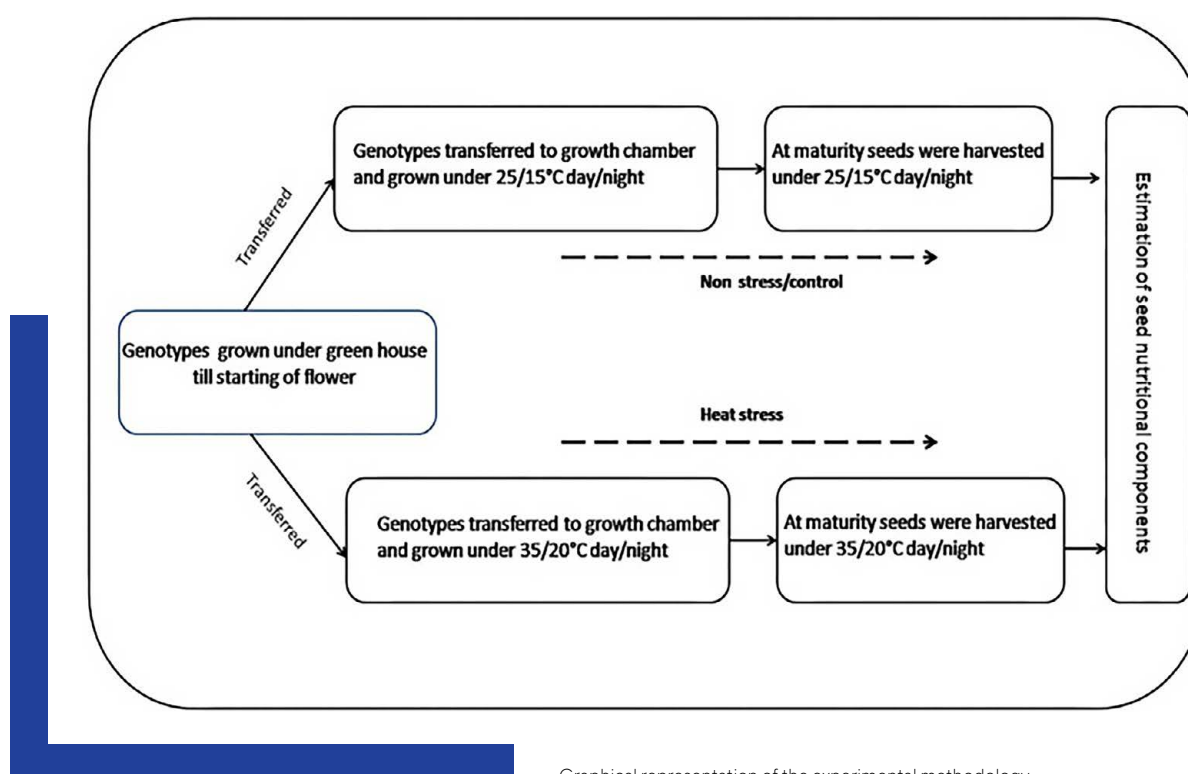
The genotypes exhibited notable genetic variations in seed carbon (C, protein (%), phosphorus (P, %), potassium (K, %), magnesium (Mg, %), sulphur (S, %), and manganese (Mn, ppm) concentrations under both conditions. However, no significant variations were observed in seed sulphur (S%), seed iron (Fe, ppm), or zinc (Zn, ppm) concentrations under NS conditions, or in seed copper (Cu, ppm) under heat stress conditions. The genotype (G) × temperature (T) interaction was significant for all traits except for seed K, indicating differential responses of chickpea genotypes to heat stress.

Correlation analyses revealed positive associations between seed carbon and protein, magnesium and phosphorus, and protein and sulphur under non-stress conditions. Under heat stress, positive correlations were observed between seed protein and magnesium and between

seed protein and phosphorus. Negative relationships were identified between calcium and potassium under non-stress conditions, and between calcium and potassium and between iron and copper under heat stress conditions.

The findings demonstrated that episodic heat stress adversely affects seed nutritional quality and seed yield. These results highlight the importance of continued research aimed at developing heat-tolerant chickpea cultivars with improved seed nutritional characteristics.

This research is supported by USAID through a Cooperative Agreement award (AID-OAA-L-14-00006).



Graphical representation of the experimental methodology.

Phenology variation in canola restorer and conventional germplasm: implications for hybrid seed production and adaptation

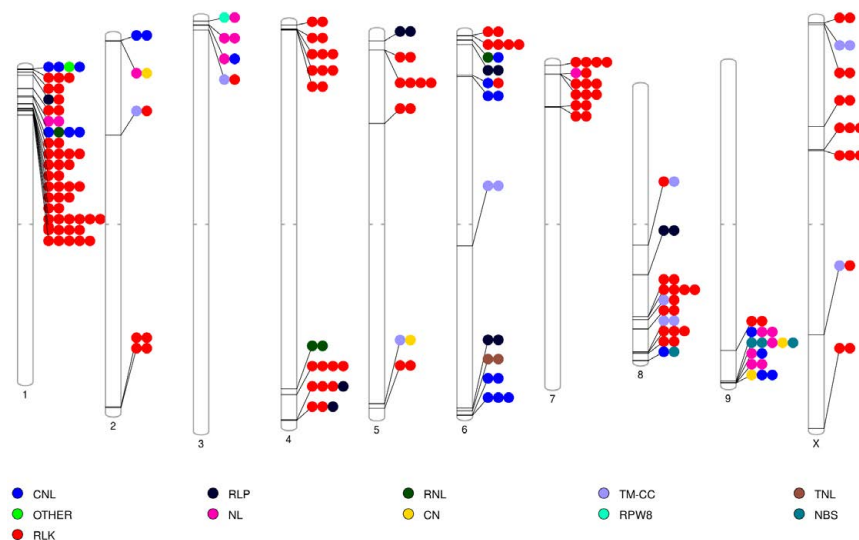
Project team: Professor Jacqueline Batley¹ (project leader; jacquelin.batley@uwa.edu.au), Dr Rajesh Natarajan¹, Sukanta Bala¹, Dr Nur Shuhadah Mohd Saad¹

Collaborating organisations: ¹UWA; ²Nufarm Pty Ltd

Flowering time and phenology are critical determinants of canola yield and adaptation in Australian environments. Genotype-by-environment interactions involving vernalisation and photoperiod requirements substantially alter flowering time and yield potential across production regions, seasons, and sowing times. Poorly matched phenology exposes crops to frost at early reproductive stages, heat and terminal drought during grain fill, or results in incomplete maturation before harvest.

Commercially released canola (*Brassica napus*) cultivars are predominantly F1 hybrids produced through cytoplasmic male sterility (CMS) systems such as Ogura. In CMS-based hybrid systems, A lines carry male-sterile cytoplasm, B lines share the same nuclear background but have normal cytoplasm to maintain the A line, and R lines carry dominant nuclear genes that restore pollen fertility. Breeding programs optimise phenology for grain yield by selecting parental lines with appropriate genetic variation and favourable heterotic interactions. However, phenology also governs flowering synchrony between A and R parents in hybrid seed production,





Ideogram showing the chromosomal positions of resistance gene analogues (RGAs) in the SDFBb haplotype. Individual chromosomes (chr1–chr9 and chrX) are displayed vertically, with coloured markers indicating the genomic locations of annotated RGA loci. Colours denote RGA classes, including receptor-like kinases (RLKs), receptor-like proteins (RLPs), NLR subclasses (CNL, NL, CN, RNL, TNL, RPW8, and NBS), and transmembrane coiled-coil (TM-CC) proteins. Clusters were defined as two or more RGAs located within 10 kb on the same chromosome, and spatial grouping of markers reflects these clustered regions along each chromosome.

Powdery mildew infection on *Cannabis sativa* L.

Molecular mechanisms underlying powdery mildew resistance in *Cannabis sativa* L.

Project team:

Professor Jacqueline Batley¹ (project leader; jacqueline.batley@uwa.edu.au), Dr Aria Dolatabadian¹, Dr Rajesh Natarajan¹, Associate Professor Monika Doblin²

Collaborating organisations:

¹UWA;

²La Trobe

Cannabis sativa L. is a medically important crop with significant pharmaceutical and industrial value; however, its production is highly vulnerable to powdery mildew infection caused by *Golovinomyces ambrosiae*, which can substantially reduce yield and product quality. Current management strategies are limited by strict regulatory constraints on chemical treatments and a reliance on clonal propagation of elite germplasm, which reduces genetic diversity and increases susceptibility to pathogen outbreaks. To address this, this project investigates both resistance and susceptibility mechanisms underpinning host–pathogen interactions in *C. sativa*. Genome-wide identification of resistance gene analogues (RGAs) using bioinformatic pipelines enables the cataloguing of immune receptor diversity, including nucleotide-binding leucine-rich repeat proteins (NLRs), receptor-like kinases (RLKs), and receptor-like proteins (RLPs), and facilitates analysis of their distribution, variation, and clustering

across phased haplotypes. In parallel, this project focuses on Mildew Locus O (MLO) susceptibility genes, which act as negative regulators of plant defence and are widely associated with powdery mildew susceptibility across angiosperms. Loss-of-function mutations in MLO genes have been shown to confer broad-spectrum resistance, making them strong candidates for targeted manipulation in *C. sativa*.

A major limitation in translating these insights into applied outcomes is the recalcitrance of *C. sativa* to tissue culture and genetic transformation, which restricts functional validation and genome editing. Candidate CsMLO genes will be functionally validated through heterologous expression in *Arabidopsis thaliana* mutant backgrounds to confirm their role in susceptibility and to delineate functional domains associated with infection. These findings will inform the design of CRISPR/Cas9 constructs targeting CsMLO genes for loss-of-function mutagenesis. To support this, Agrobacterium-mediated transformation approaches will be applied alongside optimisation of tissue culture and regeneration conditions, including the use of developmental regulator chimeras such as GRF–GIF to improve regeneration efficiency and recovery of edited plants.

Edited lines will be molecularly validated and phenotyped for resistance to powdery mildew infection.

Progress to date has applied genome-wide RGA prediction approaches to haplotype-resolved *C. sativa* genomes, enabling comparative analysis of resistance gene content, distribution, and structural organisation across haplotypes. Collectively, this project will provide a comprehensive analysis of resistance gene architecture alongside mechanistic insight into susceptibility pathways, and will explore the development of a reproducible genome editing pipeline for *C. sativa*. These outcomes will support the development of disease-resistant cultivars and provide a foundation for broader biotechnological applications, contributing to the long-term sustainability and resilience of medicinal cannabis production systems.

This research is supported by ARC.

Biochar and moisture variability shape soil carbon pools via microbial carbon-degrading genes

Project team: Professor Na Yu^{2,3,4,5} (project leader; sausoilyn@syau.edu.cn), Dr Yue Pan^{2,3,4,5}, Dr Tingting Tan^{2,3,4,5}, Dr Jie Meng^{2,3,4,5}, Dr Hongpeng Guo^{2,3,4,5}, Dr Yino Dong^{2,3,4,5}, Dr Yukui Cui^{2,3,4,5}, Dr Xinxin Jin^{2,3,4,5}, Dr Yuling Zhang^{2,3,4,5}, Dr Professor Hongtao Zou^{2,3,4,5}, Professor Nanthi Bolan¹, Hackett Professor Kadambot Siddique¹

Collaborating organisations: ¹UWA; ²Shenyang Agricultural University, China; ³Ministry of Agriculture and Rural Affairs, China; ⁴National Engineering Research Centre for Efficient Utilisation of Soil and Fertiliser Resources, China; ⁵Shenyang Key Laboratory of Intelligent Manufacturing of Microbial Fertilisers, China

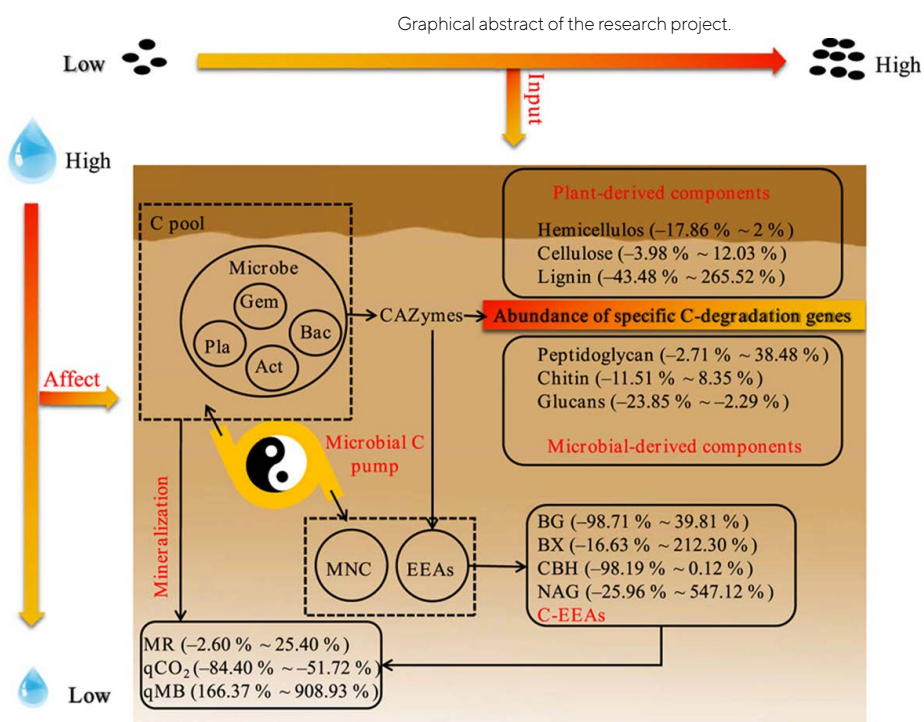
Microbially derived organic carbon is a key component of the soil carbon pool. Shifts in microbial communities and their associated functional genes—triggered by moisture variability and biochar addition—can influence the composition and stability of soil organic carbon (SOC). However, the microbial processes involved in SOC formation and degradation under different biochar levels and moisture variability intensities remain unclear. To address this, the team conducted a 90-day microcosmic incubation using three levels of biochar

addition (C0: 0, C1: 1 per cent, C2: 2 per cent, w/w) and three moisture regimes (W0: constant moisture, W1: high-intensity variability, W2: low-intensity variability) to analysed microbial communities, carbohydrase activity, C-degrading genes, and C, N, and P enzyme activities to trace and characterise microbial contributions to SOC formation. The results showed a shift in the dominant soil microbial community from Actinomycetes to Ascomycetes with increasing moisture variability. Microbial biomass carbon increased by 158–900 per cent relative to C0W0, peaking under C2W1. This stimulation enhanced microbial carbon sequestration under high moisture variability while simultaneously accelerating the decomposition of both plant- and microbial-derived carbon. Biochar addition exerted only a marginal, non-significant inhibitory effect on the decomposition of either carbon source ($P > 0.05$).

Functional gene analysis revealed that 62 per cent of carbohydrate-active enzymes (CAZymes) targeted plant-derived components significantly exceeding the 38 per cent targeting microbial-derived components, indicating a significantly stronger degradation potential for plant residues under varying

moisture conditions. This process was genetically regulated, as shown by the concurrent increase in carbon-degrading gene abundance and corresponding enzyme activities. Consequently, microbial activity was efficiently modulated, with carbon use efficiency increasing by up to 767 per cent compared with the C0W0. Moisture variability and its interaction with biochar significantly ($P < 0.05$) or highly significantly ($P < 0.01$) affected these microbial indicators. This study reveals a moisture-driven microbial “carbon pump” operating through coordinated gene–enzyme–community regulation. Within this framework, up-regulated carbon-degrading genes align with enzyme activities to channel plant-derived carbon into stable SOC. The C2W1 treatment achieved the highest SOC stabilisation, offering a theoretical basis for managing SOC under extreme climate conditions and advancing mechanistic understanding of microbe-mediated carbon dynamics.

This research was supported by the National Key R&D Program of China (Grant No. 2022YFD1500600).



Integrated effects of rainwater harvesting and organic fertilisation on soil structure and aggregates in a rainfed orchards on the Loess Plateau

Project team: Professor Shufang Wu² (project leader; wsfjs@163.com), Dr Wenjing Su², Dr Bin Li², Dr Xiaofeng Ouyang², Professor Hao Feng², Hackett Professor Kadambot Siddique¹

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

Rainwater harvesting (WH) and organic fertiliser (OF) are important strategies to alleviate water shortage and soil degradation in rain-fed orchards on China's Loess Plateau. However, the integrated mechanism of WH and OF combined with soil improvement has been rarely studied. Therefore, the team implemented a novel WHIOF system integrating rainwater collection, supplementary irrigation, and organic fertiliser in a rainfed apple orchard. This system was designed to improve soil quality and sustainability in rain-fed apple orchards on China's Loess Plateau, where water scarcity and soil degradation severely limit productivity. A field experiment compared conventional management, rainwater harvesting alone, harvesting with irrigation, and two levels of organic

fertilisation combined with irrigation. Five treatments were tested: conventional management (CK), WH only, WH with irrigation (WHI), WHI + low OF (WHIOF1), and WHI + high OF (WHIOF2).

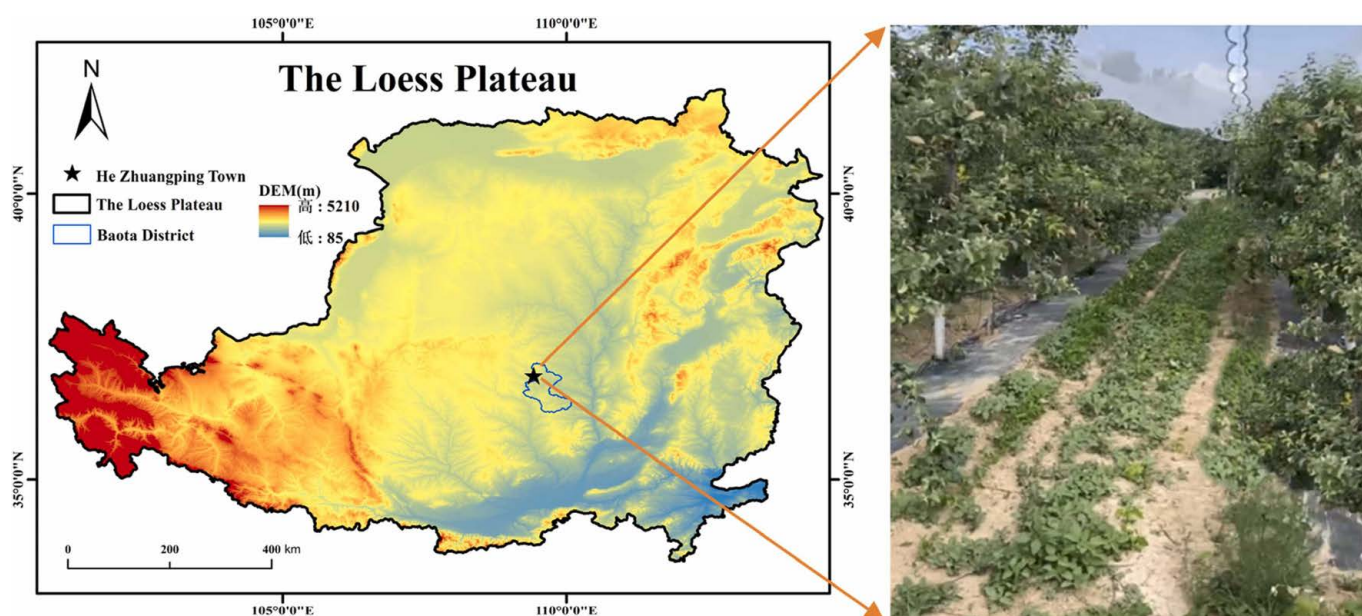
The results indicate that:

1. WHIOF significantly improved soil physical properties by reducing soil bulk density (BD), increasing porosity and enhancing saturated hydraulic conductivity (Ks). Organic fertilisation elevated soil organic matter (SOM) content and substantially increased the proportion of macroaggregates.
2. WHIOF amplified soil surface charge density (σ_0), specific surface area (SSA), and interparticle attraction by modulating electrostatic and van der Waals forces, thereby reducing aggregate disruption (PAD).
3. Water-stable aggregate stability was tightly linked to SOM ($r = 0.96$, $p < 0.01$); surface electrochemical properties (e.g., SSA) governed aggregate cohesion.

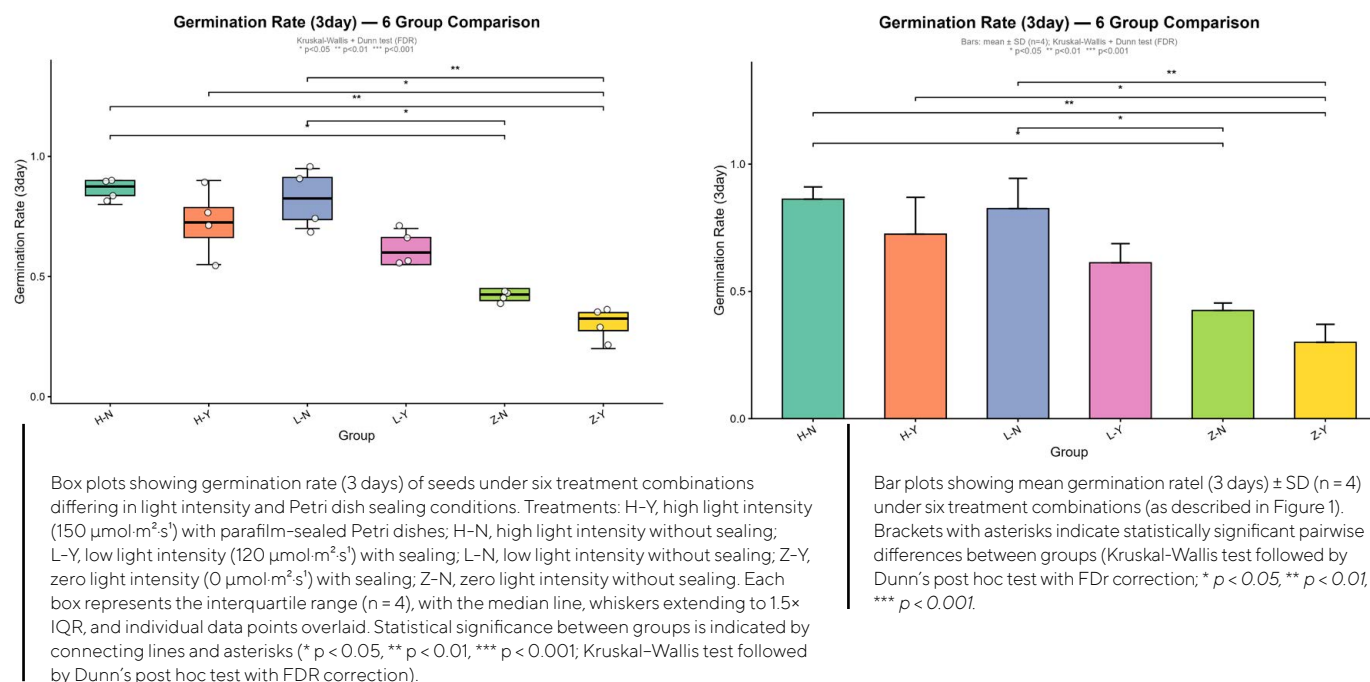
Overall, these improvements in aggregate stability further enhance soil water

retention capacity, mitigates erosion risks, optimises water and nutrient use efficiency, and provides a healthy root environment for apple trees. These findings provide a mechanistic basis for sustainable soil management in rainfed apple orchards, demonstrating WHIOF as an innovative approach to enhance soil fertility and industry sustainability.

This research is supported by the National Key R&D Program of China (2023YFD1900300).



Location of experimental site on the Loess Plateau.



The molecular mechanisms of salinity and blackleg disease resistance in *Brassica napus*

Project team: Professor Jacqueline Batley¹, (project leader; jacqueline.batley@uwa.edu.au), Dr Aria Dolatabadian¹, Dr Junrey Amas¹, Chi Zhang¹

Collaborating organisation: ¹UWA

With an average annual production of around 4 million tonnes worth over A\$4 billion, canola is Australia's third most valuable grain crop. However, biotic and abiotic stresses, including salinity stress and blackleg disease, threaten its production. This project will uncover genes that regulate salt resistance, as well as genes and regulatory pathways underlying blackleg resistance and which control canola's response to these stresses, which remain poorly understood.

This research primarily aims to elucidate the molecular mechanisms underlying canola's responses to the combined blackleg and salinity stress and to integrate these insights into abiotic and biotic stress adaptation to advance crop resilience. Specifically, to achieve this, a stepwise experimental framework has been designed.

First, salt stress will be applied to lines exhibiting contrasting phenotypes in response to blackleg disease, which further enables the identification of lines that vary in their response to different stress conditions, thereby confirming the materials for subsequent experiments.

Second, to elucidate the mechanisms underlying the *B. napus* response to combined stress (blackleg disease and

salinity), materials selected from step one will be grown under different stress and control conditions, and multi-omics sequencing will be performed on these materials. Differential expression analysis and multi-omics integration will identify crucial interactions and key molecular markers (e.g., significant metabolites, genes, or proteins) that play pivotal roles in the combined stress response signalling pathway.

Third, to validate the hypotheses regarding novel genes and regulatory interactions derived from multi-omics analysis in step two, Y1H and Y2H assays will be utilised to validate the gene-protein interactions and protein-protein interactions derived from the inferred regulatory network. Full-length cDNA cloning will also be applied to characterise the novel gene or its isoforms identified by omics analysis. Expected outcomes include molecular markers to support breeders in developing varieties resilient to salinity stress and blackleg disease, thereby reducing financial losses due to environmental challenges.

The current stage of this project focuses on optimising seed germination conditions, with the primary aim of establishing a robust system to evaluate the salinity tolerance of different canola lines.

Preliminary experiments have been conducted to test different NaCl concentrations for simulating salt stress. Initial results suggest that the DG1901TT, a commercial cultivar, shows potential for salt

tolerance. The observed variability among replicates also provides valuable guidance for further optimisation. Accordingly, efforts are currently focused on refining germination conditions to make the experimental process more robust and reproducible.

As part of this optimisation process, the effect of light conditions on germination was examined. Preliminary observations in Germination Rate indicate that a light intensity of 150 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ promotes better germination compared to dark conditions (0 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$).

Other experimental parameters, including sterile seed contamination control and NaCl concentration gradients, remain to be systematically optimised. The next steps will include:

- Optimising germination conditions (e.g., light regime, temperature, and growth setup)
- Refining NaCl concentration ranges to identify an appropriate level for simulating salinity stress.
- Improving experimental reproducibility to reduce variability and ensure robust phenotypic assessment.

Overall, while preliminary results indicate potential salt tolerance in the tested line, further optimisation of germination conditions is necessary to establish a stable and reliable experimental system.

This research was funded by ARC (FL230100030) and GRDC (UWA2307-002RTX).

Morphological, molecular and physiological strategies for insect resistance

Project team: Professor Jacqueline Batley¹, (project leader; jacqueline.batley@uwa.edu.au), Dr Jing Li¹; Dr Thomas Bergmann¹; Friederike Goettmann¹, Jake Cummane¹; Jelena Um^{1,2}; Miguel Vaz Pereira¹

Collaborating organisations: ¹UWA;

²Nagoya University, Japan; Murdoch University; John Innes Centre, UK; Rothamsted Research, UK

Canola (*Brassica napus*) is an important crop globally, particularly for Australian agriculture and the economy. However, insect pests cause millions of dollars in damage worldwide each year. This project proposes two solutions by exploring the *Brassica* genome to identify novel sources of resistance.

One solution aims to identify novel sterol profiles in canola that confer protection against phytophagous insects by utilising existing knowledge of sterol pathway genes and examining how gene mutations affect sterol profiles and phenotypes in the Brassicaceae family. This relies on phytophagous insects' inability to utilise all sterols to produce their own moulting hormones, which are hormones essential for insect development.

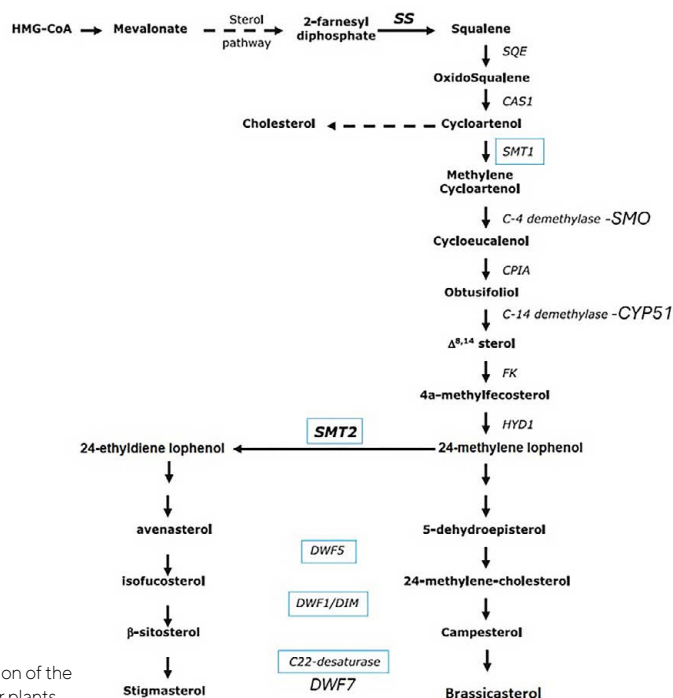
In 2025, a *Brassica rapa* TILLING (Targeting Induced Local Lesions in Genomes) population was used in feeding assays with diamondback moth (DBM) and the plants' sterol composition was analysed using Gas Chromatography–Mass Spectrometry (GC–MS), demonstrating that plant sterol quality influences DBM development. Some of these lines were also studied in collaboration with researchers in the UK, where feeding trials with cabbage stem flea beetles and quantitative GC analysis were performed. Furthermore, a CRISPR protocol that avoids the use of exogenous DNA is currently being developed in canola to produce insect-resistant lines.

A second solution aims to identify new sources and genes involved in trichome formation in *Brassica* species. Trichomes are hair-like structures that form a natural protective barrier against pests and biotic stresses. They are present in wild *Brassica oleracea* species but only to a limited extent in *B. napus*. Therefore, enhancing trichome formation in *B. napus* is a promising strategy to improve genetic resistance while reducing dependence on chemical insecticides.

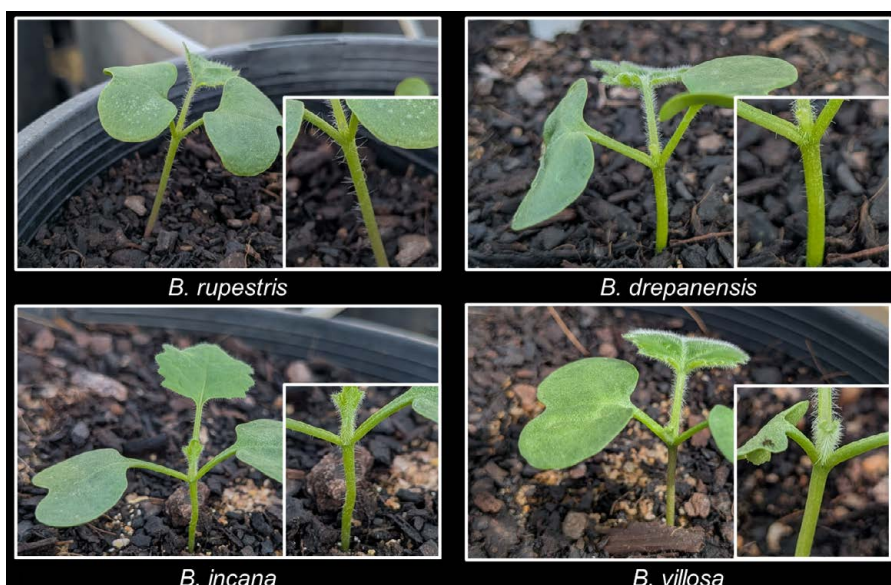
For this, TILLING populations of *B. oleracea* and *B. napus* are being screened and analysed for mutations in trichome-related genes to utilise these mutations in novel breeding approaches. In parallel, a targeted CRISPR/Cas9 Knockout of trichome-related genes is performed to modify trichome formation in *B. napus* via gene editing.

This project will provide more sustainable approaches to insect pest management, enabling the use of fewer pesticides in the field while maintaining high yields. Plant breeders can use the results of this research to develop new insect-resistant canola strains.

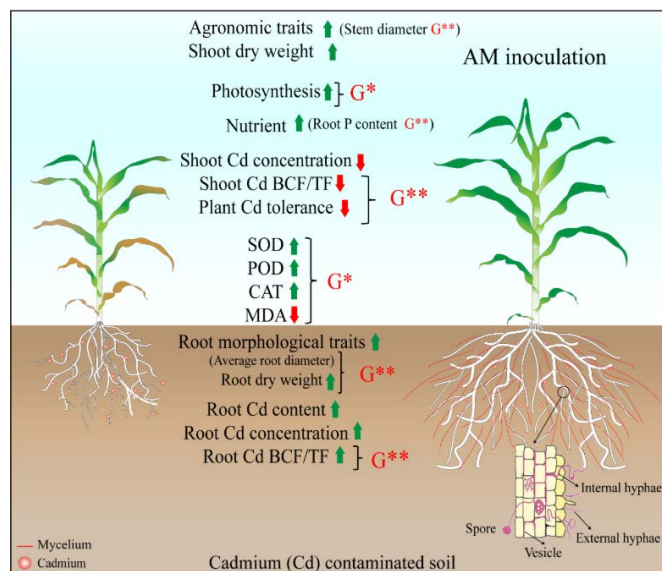
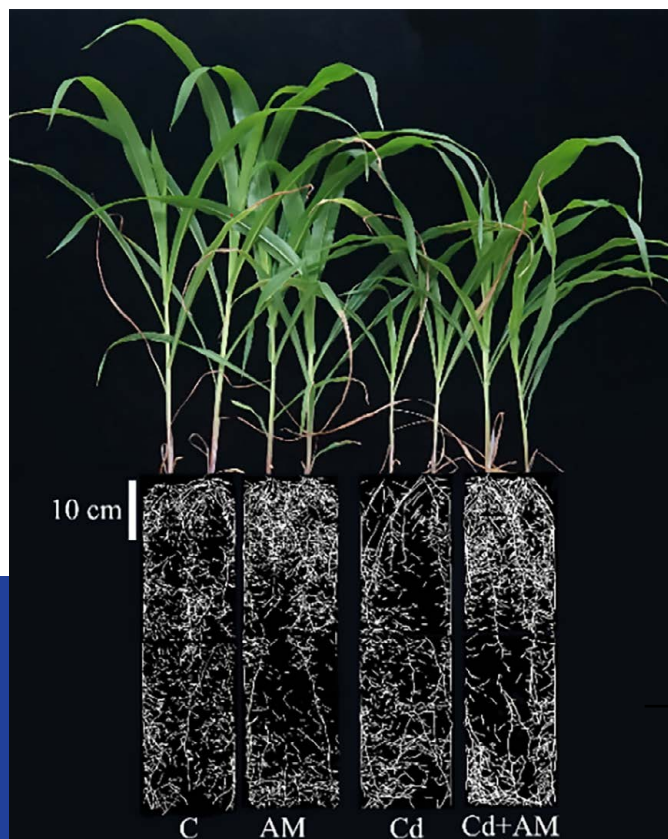
This research was funded by GRDC and ARC.



Schematic representation of the sterol pathway in higher plants.



Natural variation of trichomes in wild *Brassica oleracea* species.



Mechanism of the mitigation strategy of arbuscular mycorrhizal (AM) fungi on maize growth under cadmium (Cd) stress.

Plants and root systems of maize genotype Zhongke11 (Cd-sensitive) grown in soil amended with or without cadmium (Cd, 60 mgkg⁻¹ soil) and inoculated with or without arbuscular mycorrhizal (AM) fungi. Plant shoots were photographed and roots were traced on the clear wall of rhizoboxes 56 days after transplanting (DAT) (bar = 10 cm).

Arbuscular mycorrhizal fungi mitigate cadmium stress in maize

Project team: Dr Yinglong Chen¹ (project leader; Yinglong.Chen@uwa.edu.au), Qiqiang Kuang², Yujie Wu², Yamin Gao², Dr Tingting An^{2,3}, Dr Shuo Liu², Dr Liyan Liang^{2,4}, Professor Bingcheng Xu², Professor Suiqi Zhang², Professor Min Yu⁵, Professor Sergey Shabala¹

Collaborating organisations: ¹UWA; ²Northwest A&F University, China; ³Henan Institute of Science and Technology, China; ⁴Gansu Agricultural University, China; ⁵Foshan University, China

Soil cadmium (Cd) pollution poses a significant environmental threat, impacting global food security and human health. Recent studies have highlighted the potential of arbuscular mycorrhizal (AM) fungi to protect crops from various heavy metal stresses, including Cd toxicity.

To elucidate the tolerance mechanisms of maize in response to Cd toxicity under AM symbiosis, this study used two maize genotypes with contrasting Cd tolerance: Zhengdan958 (Cd-tolerant) and Zhongke11 (Cd-sensitive).

Rhizobox experiments were conducted with and without AM inoculation, alongside Cd treatment. The results revealed that Cd stress severely impaired growth and root development in both genotypes. However, AM symbiosis significantly improved plant height, stem diameter, biomass, root morphology, photosynthetic capacity, nutrient uptake, antioxidant enzyme activity, root Cd content, and concentration, while also reducing lipid peroxidation and shoot Cd accumulation in both genotypes. Notably, AM symbiosis had a more

pronounced effect on stem diameter (increased 55 per cent), root dry weight (118 per cent), root superoxide dismutase (42 per cent), and peroxidase activity (209 per cent), as well as shoot translocation factor (77 per cent) in Zhongke11 compared to Zhengdan958. Overall, AM symbiosis alleviated Cd toxicity in maize through multiple mechanisms, including enhanced photosynthesis, nutrient uptake, antioxidant defenses, and modulation of Cd transport and accumulation. This study provides valuable insights into the potential application of Cd-tolerant maize genotypes and AM symbiosis for managing Cd-contaminated soils.

This research is supported by NNSFC (42077055) and ARC (FT210100902).

Soybean genotypes with contrasting root system size differ in saline-alkaline tolerance

Project team: Dr Yinglong Chen¹ (project leader; Yinglong.Chen@uwa.edu.au), Dr Shuo Liu², Dr Tingting An², Yamin Gao², Qiqiang Kuang², Professor Bingcheng Xu², Professor Suiqi Zhang², Professor Xiping Deng, Professor Tuanjie Zhao, Professor Hon-Ming Lam, Professor Sergey Shabala¹

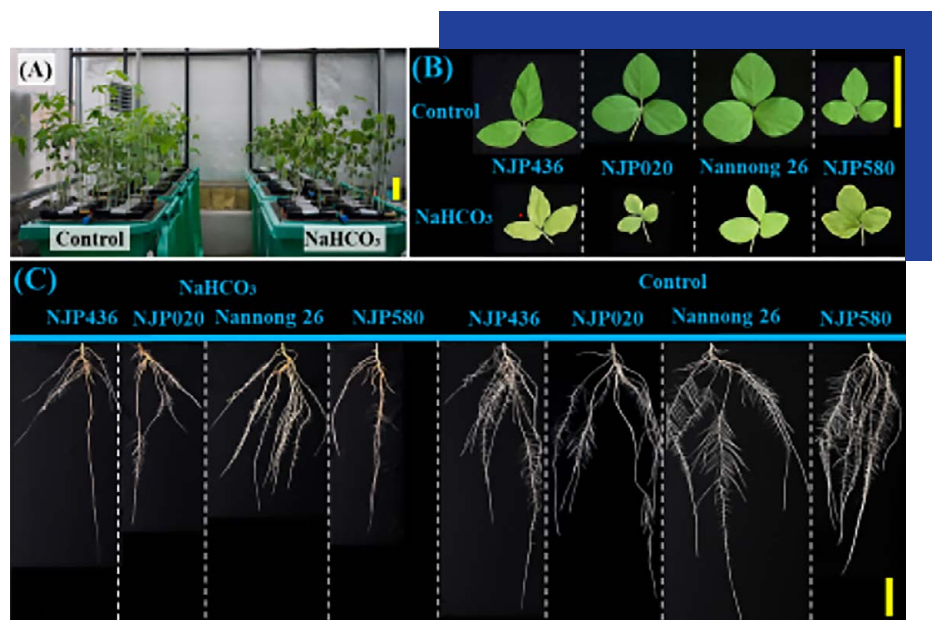
Collaborating organisations: ¹UWA; ²Northwest A&F University, China; ³Henan Institute of Science and Technology, China; ⁴Nanjing Agricultural University, China; ⁵Chinese University of Hong Kong, China; ⁶Foshan University, China

Soybean (*Glycine max* L. Merr.) is highly susceptible to saline-alkaline conditions, exhibiting significant genotypic variability in tolerance. The root system plays a pivotal role in saline-alkaline resistance, yet the precise mechanisms, particularly those related to root morphological traits, remain unclear. This study explores genotypic variations in root morphology and saline-alkaline tolerance among diverse soybean genotypes and examines the relationship between root system growth and tolerance mechanisms.

Eight soybean genotypes with varying root system sizes were evaluated for saline-alkaline tolerance 26 days after transplantation. Plants were subjected to NaHCO₃ stress (0 and 30 mmol L⁻¹) for five days using a semi-hydroponic phenotyping platform in a glasshouse. Saline-alkaline stress caused significant variation in 20 shoot and root traits, as well as 23 physiological and biochemical traits. Transcriptional profiling revealed differential expression of key genes, including *GmHKT1;4*, *GmPLMT*, *GmERF8*, and *GmWRKY12*. Based on the mean relative shoot dry mass ratio, the eight genotypes were categorised as sensitive, moderately tolerant, or tolerant.

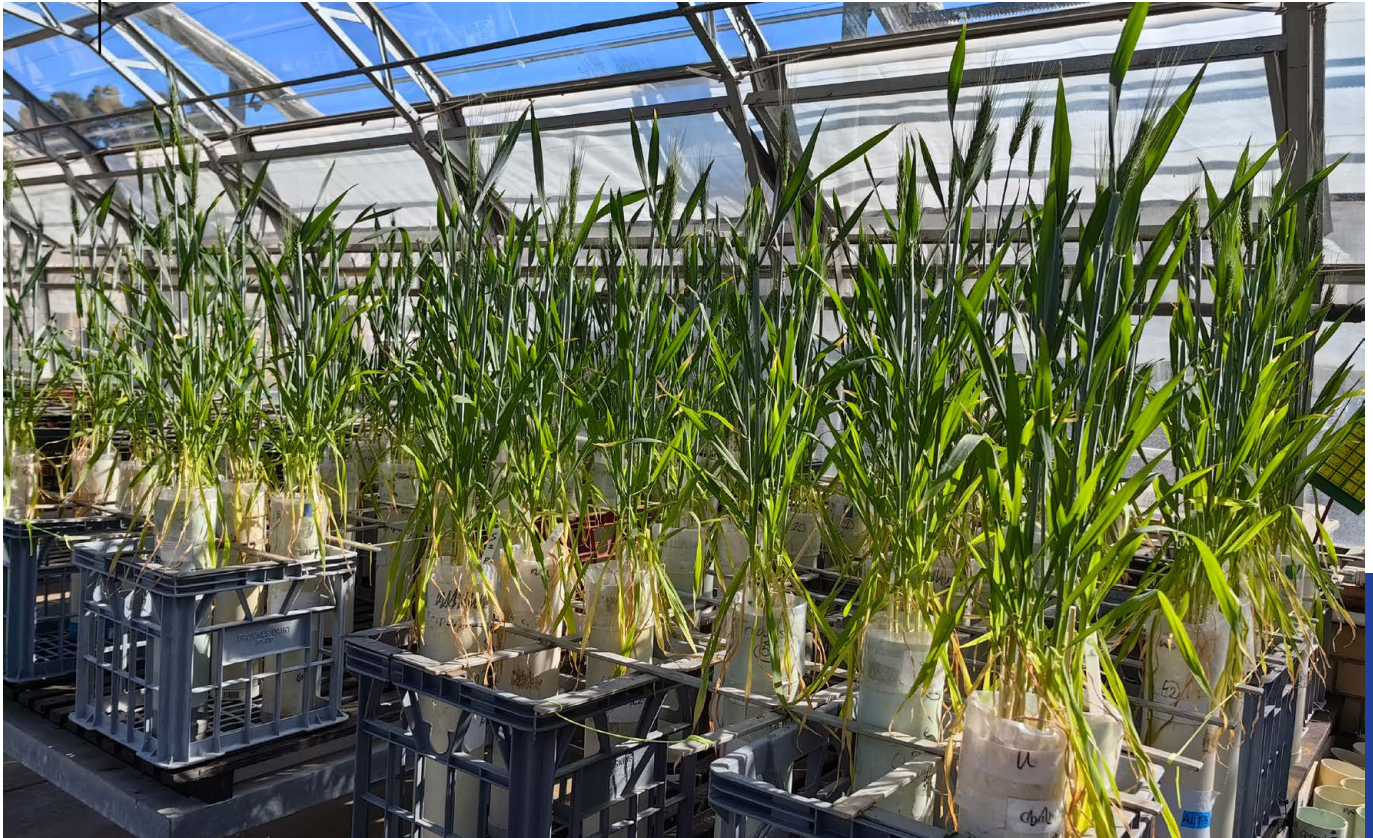
Under saline-alkaline stress, the tolerant, large-rooted genotype Nannong 26 showed increased Ca²⁺ accumulation and up-regulation of *GmHKT1;4* and *GmPLMT* in both shoots and roots. In contrast, the tolerant, smaller-rooted genotype NJP580 exhibited higher K⁺ accumulation and up-regulation of *GmERF8* and *GmWRKY12* in shoots and roots. Root dry mass, fine root length, and the upper-to-lower biomass allocation ratio emerged as potential indicators of saline-alkaline tolerance in soybean. These traits may serve as useful proxies for early-stage screening of tolerant genotypes. The identified saline-alkaline-tolerant genotypes offer promise for cultivation in saline-alkaline soils and for breeding high-yielding, stress-tolerant soybean hybrids.

This research is supported by NNSFC (42077055) and ARC (FT210100902).



Experimental layout and root phenotype data. Plants were cultivated for 30 days after transfer (DAT) in a semi-hydroponic system without NaHCO₃ (control) or with NaHCO₃ for five days (treatment) (A). Panels B and C show typical images of the third compound leaves (B) and roots (C) of four selected genotypes at 30 DAT. Yellow bar = 10 cm.

Wheat plants grew in acidic soil with or without lime amendments.



Incorporating lime into acidic subsoil improved root growth and rhizosphere microbial activity in wheat

Project team: Dr Yinglong Chen¹ (project leader; Yinglong.Chen@uwa.edu.au), Bingchen Li¹, Dr Gaus Azam^{1,2}, Dr Kanch Wickramarachchi^{1,2}, Dr Stephen Davies², Professor Sergey Shabala¹

Collaborating organisations: ¹UWA; ²DPIRD; Northwest A&F University, China; Nanjing Agricultural University, China; The Chinese University of Hong Kong, China; Foshan University, China

Soil acidification is a widespread problem threatening sustainable crop production in many agricultural regions worldwide. In Western Australian agricultural regions, 70 per cent of surface soils and approximately 50 per cent of subsurface soils are below the target pH (CaCl_2) for optimal crop growth. Lime application is one of the common practices to improve soil acidification, as it neutralises soil acidity, raises pH, and enhances nutrient availability. However, the movement of lime from topsoil to subsoil is slow, leaving the deeper soil layers in unfavourable conditions for crop growth. Recent research demonstrates the potential role of rhizosphere microbes in mitigating environmental stress. However, how

lime-based soil re-engineering affects soil microbial communities remains poorly understood.

Acidic subsoil (pH 4.6 in CaCl_2 , 10–40 cm) was used, and neutral topsoil (0–10 cm) was collected from a farm in Grass Valley in the wheatbelt region of Western Australia, after air-drying and sieving, to reconstruct soil profiles in 40-cm-deep PVC columns. The subsoils were amended with lime (1 g kg^{-1} soil). Half of the soils were steam sterilised to compare microbial activity. Wheat plants were assessed at the tillering and milking development stages to analyse root morphology, photosynthetic performance, soil pH, and microbial biomass carbon (MBC). Results revealed that lime application significantly enhanced microbial biomass in the subsoil during the milking stage. Moreover, there was a lime $\times$ sterilisation interaction for the pH in both topsoil and subsoil at both growth stages. Sterilisation significantly increased intercellular CO_2 concentration (C_i) and stomatal conductance (G_s).

Principal component analysis demonstrated that soil re-engineering promoted subsoil root proliferation in the presence of active

microbial communities at the tillering stage. During the milk development stage, soil re-engineering and active microbial presence greatly enhanced canopy greenness, photosynthetic activity, and colour saturation.

In conclusion, soil re-engineering with lime significantly improved soil pH in the subsoil and promoted wheat growth, and microbial activity. In return, improved soil microbial activity promoted root growth in the subsoil by altering root morphology, regulating stomatal behaviour, and enhancing canopy photosynthetic performance and colour vitality.

This research is supported by GRDC (DAW2407-001SPX), DPIRD and UWA.



Wheat column experiments in the glasshouse.

Phosphorus availability reshapes the coordination between remobilisation and post-anthesis uptake, thereby determining grain P accumulation in wheat

Project team: Dr Jiayin Pang¹ (project leader; jiayin.pang@uwa.edu.au), Emeritus Professor Hans Lambers¹, Hackett Professor Kadambot Siddique¹, Associate Professor Peta Clode¹

Collaborating organisations: ¹UWA

Phosphorus (P) is a critical nutrient limiting crop productivity worldwide, yet its inefficient use in agricultural systems leads to both economic and environmental challenges. Grain P accumulation in cereals depends on two major processes: post-anthesis P uptake and the remobilisation of internal P reserves. However, the organ-specific contributions and coordination of phosphorus remobilisation efficiency (PRE) remain poorly understood.

This project aims to quantify organ-specific PRE across multiple wheat organs and to investigate how different organs' PRE coordinates to regulate grain P accumulation under contrasting phosphorus supply conditions.

In 2025, the research team conducted controlled experiments using contrasting P treatments to quantify PRE. It was demonstrated that PRE exhibits strong organ-specific and P-dependent patterns, with aboveground organs showing enhanced remobilisation under low-P conditions. At the same time, the roots played a greater role under high-P conditions. Importantly, coordinated relationships among organ-specific PRE were identified, revealing distinct remobilisation strategies under different

P regimes. Additionally, it was shown that under P limitation, increased seed dry weight was associated with reduced seed P and phytate concentrations, indicating a dilution effect.

This study provides new insights into the coordination of phosphorus remobilisation at the organ level and its interaction with external P uptake. By improving the understanding of P allocation strategies in crops, these findings contribute to the development of more P-efficient wheat varieties and sustainable nutrient management practices.

This research is supported by ARC (LP200100341), CSC and UWA top-up scholarship.

Host-pathogen-microbiome interactions: Unearthing mycobiome assembly in the *Leptosphaeria maculans* - *Brassica napus* pathosystem at two months post-sowing

Project team: Professor Jacqueline Batley¹ (project leader; jacqueline.batley@uwa.edu.au), Maria Lee¹, Dr Angela van De Wouw², Dr Aria Dolatabadian¹, Dr Sarah Lock¹

Collaborating organisations: ¹UWA; ²University of Melbourne

Blackleg disease, caused by the fungus *Leptosphaeria maculans*, poses a serious problem for the canola (*Brassica napus*) industry. The *B. napus* - *L. Maculans* pathosystem is a well-studied model in which interactions adhere to the gene-for-gene concept. While extensive research has focused on host resistance and pathogen virulence, the microbial community's role in rhizosphere disease development remains understudied. There is a gap in understanding of how resistance genes and disease progression at specific stages of host development may structure pathogenic or beneficial members of the plant host microbiota.

This study aims to investigate fungal community structure in the rhizospheres of different canola cultivars under glasshouse conditions. Bacterial microbiota recruitment within the rhizosphere will also be characterised later to complement the fungal taxa profiles presented here. In addition, field sampling conducted during the Autumn and Winter of 2025 will provide further ecological evidence on how abiotic factors and anthropogenic activities can shape the canola rhizosphere core mycobiome in Western Australia.

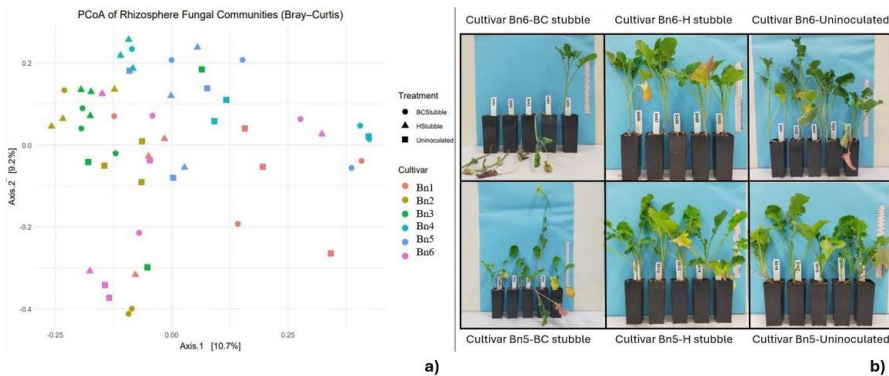
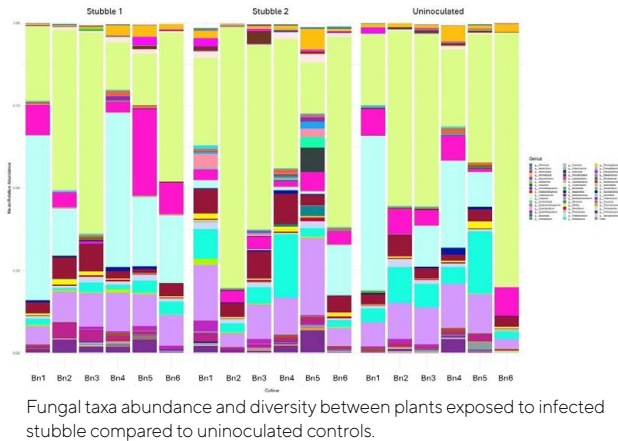
Canola cultivars with different blackleg resistance levels, ranging from susceptible to moderately and highly resistant, were exposed to two blackleg stubble sources collected from paddocks previously planted with different canola cultivars. Stubbles were confirmed to infect specific canola populations. A third set of replicates was set aside as uninoculated controls. Plants were maintained in a humidity chamber at 27°C for 72 hrs to promote ascospore release. All plants were transferred to the glasshouse up to 2 months before sampling. Soil samples from the rhizosphere were collected in triplicate from different sites within individual

plants. DNA extractions, amplification with selected primer sets targeting 18S rRNA, and high-throughput sequencing (Illumina MiSeq) were completed during the first half of 2025. Fungal alpha- and beta-diversity, including keystone species, were analysed using Mothur and R statistical software. Taxonomic assignment for ASVs was based on the UNITE database.

In this study, core fungal taxa associated with blackleg-infected and healthy plants across varying levels of resistance were identified. Common taxa included: *Clitopilus*, *Lasiobolium*, *Nematocytus*, *Phialophora*, and *Pseudallescheria*, whereas unique taxa such as *Infundichalara* and *Naganishia* were detected exclusively in cultivar Bn5/Stubble 2 and Bn4/Bn5, respectively. Plants exposed to Stubble 1 were marked by shifts in taxa abundance compared to uninoculated controls, indicating that pathogen-infected residues restructure the resident mycobiome. In contrast, plants exposed to Stubble 2 exhibited higher fungal diversity, with the notable exception of *Linnemannia*, which was significantly suppressed. The core mycobiome identified here was dominated by soil saprotrophs spanning the

two major fungal phyla, Ascomycota and Basidiomycota. Compared to existing studies of canola-associated fungal communities, which report dominance by pathogenic or endophytic ascomycetes such as *Trichoderma* and *Exophiala*, our findings reveal a resistance-independent saprotrophic core that persists even under blackleg pressure. The stubble inoculation method, used to mimic infection in the field environment, and the different plant growth rates account for the variability within the replicates. This study provides insights into how post-harvest residue management, specifically stubble removal, can influence mycobiome structure and disease outcomes.

This research is supported by UWA.



a) Fungal communities (beta diversity) associated with the rhizosphere exhibited no clustering in responses to the cultivars and treatments. b) Within-group variability may drive beta diversity results due to different plant growth rates and plants not being infected uniformly from the stubble.

Exploring the responses of chickpea accessions with contrasting root carboxylate exudation and root size under low phosphorus and water stress

Project team: Hackett Professor Kadambot Siddique¹ (project leader; kadambot.siddique@uwa.edu.au), Emeritus Professor Hans Lambers¹, Dr Jiayin Pang¹

Collaborating organisations: ¹UWA

Plants may produce a surplus of carbon (C) when growth is restricted by nutrient limitation and water scarcity, while photosynthesis remains comparatively unaffected. This surplus C can be transported via the phloem to sink tissues, such as under phosphorus (P) deficiency, and may ultimately influence rhizosphere exudation. Root exudation is highly species-specific and responsive to environmental conditions, with its quantity and composition shaped by nutrient deficiency, drought, soil properties, microbial communities, plant species and developmental stage.

Chickpea frequently experiences terminal drought during its reproductive phase, leading to substantial yield losses. Notably, chickpea releases large amounts of carboxylates into the rhizosphere regardless of soil P availability. It shows increased carboxylate exudation under combined drought and low-P stress compared with well-watered plants. The physiological and biochemical processes regulating carboxylate release in chickpea under drought and P deficiency warrant further investigation.

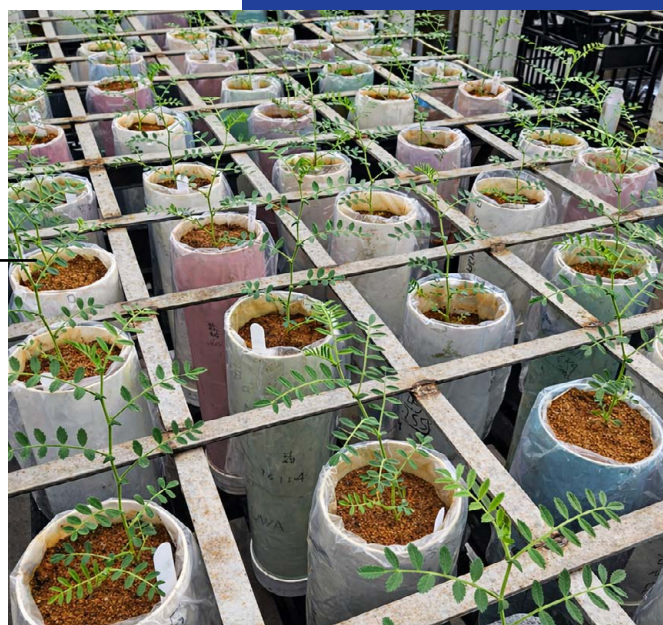
This study was conducted in the UWA glasshouse from May to August, 2025. Results showed that drought stress and its duration significantly increased root carboxylate exudation in both chickpea accessions. The accession with greater root carboxylate exudation released more root-exuded sugars and amino acids

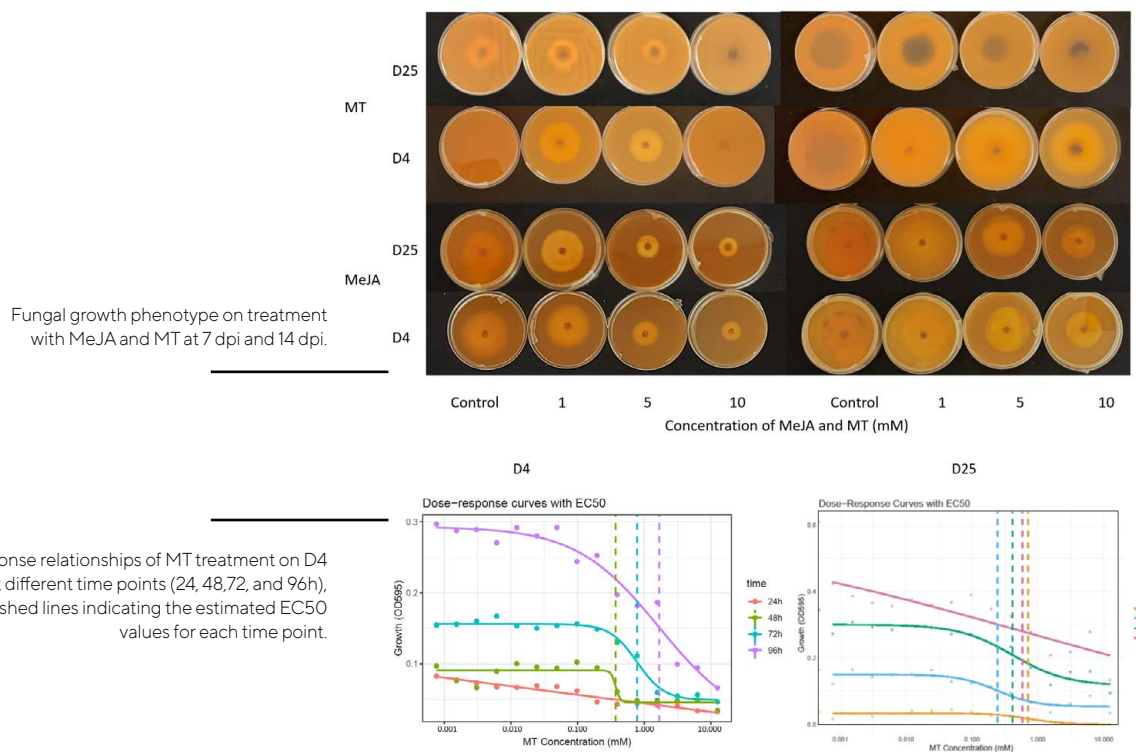
under drought stress than the accession with less root carboxylate exudation. In contrast, drought stress markedly reduced photosynthesis rates, stomatal conductance and shoot and root biomass in both accessions. Overall, the findings highlight that drought stress and its duration significantly enhance root C exudation while suppressing chickpea growth under nutrient-limited environment. The contrasting C allocation patterns highlight the importance of selecting accession with favourable root exudation traits for improving crop performance in farming systems facing concurrent drought and low phosphorus availability.

This research is supported by ARC, CSC and UWA Top-Up Scholarship.

Chickpea accessions are grown in PVC tubes before drought stress imposed in glasshouse.

Arrangement of chickpea accessions after 28 days of drought: ICC 4814_well-watered, ICC 4814_water-stressed, ICC 456_well-watered, ICC 4814_water-stressed.





Mechanisms underlying the interaction between Melatonin and Jasmonic Acid in modulating resistance against *Leptosphaeria maculans* in *Brassica napus*

Project team:

Professor Jacqueline Batley¹ (project leader; jacqueline.batley@uwa.edu.au), Joyce Zhu¹, Dr Rajesh Natarajan, Dr Sarah Lock¹

Collaborating organisations:

UWA
Blackleg disease, caused by the fungus *Leptosphaeria maculans*, is one of the most destructive diseases affecting *Brassica napus* crops, including canola (*Brassica napus*). The disease leads to severe yield and quality losses due to stem canker, posing a major threat to global canola production. Understanding the molecular mechanisms underlying plant defence responses is therefore critical for developing durable resistance strategies. Melatonin (MT) is a key metabolite involved in plant stress responses, particularly in reactive oxygen species (ROS) scavenging and cell wall reinforcement. In parallel, phytohormones such as salicylic acid (SA) and jasmonic acid (JA) play central roles in activating defence-related genes and signalling pathways. Hormone-mediated resistance is often more durable and less likely to be overcome by pathogens, making it an important focus in crop protection studies.

This study aims to investigate the role of MT-related genes in plant defence using CRISPR-Cas9 gene-editing techniques combined with phenotypic characterisation. In addition to gene function analysis, the study will explore

the interaction between MT and other hormone signalling pathways in response to *L. maculans* at both the genomic and transcriptional levels. To further examine the antifungal potential of MT and JA signalling, in vitro assays were conducted using two different *Leptosphaeria maculans* isolates (D4 and D25).

Treatments included MT and methyl jasmonates (MeJA), a JA donor, to evaluate their effects on fungal colonisation and growth. At 7 days post-infection (dpi), a clear trend was observed where MeJA and MT slowed fungal colony expansion in a concentration-dependent manner. As the concentration increased, colony diameters decreased noticeably compared to the control. At 14 dpi, the team observed that the control group exhibited vigorous hyphal growth, with the mycelium covering the entire surface of the medium. As for the treatment groups, the inhibitory effect became even more apparent, indicating that MeJA and MT maintain suppression over time. These results show that MeJA and MT exert both early and sustained inhibition on *Leptosphaeria maculans* growth.

In addition, a microtiter plate assay employed to quantify fungal growth dynamics under different treatment conditions showed that both treatments (MT and MeJA) inhibited fungal growth in a dose-dependent manner. These assays

provided a controlled framework to compare the antifungal efficacy of MT and MeJA.

Based on these results, future work will focus on elucidating the relationship between endogenous phytohormone levels and genotypes with varying resistance to *L. maculans*. High-resolution chromatography techniques, together with quantitative real-time PCR, will be employed to profile hormone dynamics and gene expression associated with defence responses. To explore the transcriptional activation of key marker genes involved in MT and JA biosynthesis and signalling pathways, CRISPR-Cas9 gene-editing technology will be used to generate targeted knockouts of candidate genes. Functional characterisation of these edited lines will provide deeper insights into how MT and JA pathways jointly regulate resistance mechanisms.

This research is expected to advance a mechanistic framework that links MT metabolism to hormone-mediated defence signalling in *B. napus*. Such knowledge will support the development of innovative strategies for enhancing durable resistance to blackleg disease, with potential applications in both molecular breeding and sustainable crop protection.

This research is supported by GRDC and ARC.

Characterisation of blackleg resistance genes in *Brassica napus*

Project team: Professor Jacqueline Batley¹ (project leader; jacqueline.batley@uwa.edu.au), Professor Dave Edwards¹, Dr Junrey Amas¹, Xavier Caguiat¹, Friederike Goettmann¹, Amanda Hewa Maithreege¹, Dr Nur Shuhadah Mohd Saad¹, Dr Rajesh Natarajan¹, Dr Maria Pazos Navarro¹, Zuhra Qayyum¹, Dr William Thomas¹, Syed Kashif Azeem Tirmizi¹, Clementine Wu¹, Professor Angela van de Wouw²

Collaborating organisations: ¹UWA; ²University of Melbourne

Canola (*Brassica napus*) is a globally significant oilseed crop with extensive applications in food, biofuel and industrial sectors. However, blackleg disease caused by the fungal pathogen *L. maculans* causes significant yield losses for canola production worldwide. The use of resistant canola varieties is one of the most effective strategies for managing blackleg disease. Nevertheless, the rapid evolution of fungal populations has overcome the genetic resistance of canola, necessitating continuous efforts to identify and functionally validate genes responsible for blackleg resistance.

This project aims to identify, characterise, and validate qualitative resistance in *B. napus* against blackleg disease, optimising and utilising advanced biotechnological approaches.

Large-scale phenotypic screening using differential isolates identified segregating resistant and susceptible lines. Long-read whole-genome sequencing for selected individuals, and a combination of whole-genome re-sequencing and genome-wide association studies identified genomic regions associated with *Rlm1* and *Rlm6*, respectively. High-throughput genotype screening and sequencing have identified one strong candidate gene for *Rlm1* and *Rlm6*. Kompetitive Allele-Specific PCR (KASP) markers were then designed to target SNPs that can differentiate resistant and susceptible alleles for each gene.



Regenerating *B. napus* hypocotyl explant, 75d post-transformation.

Additional research is underway to identify and characterise novel blackleg R genes in commercial canola cultivars.

Transient gene expression is one of the first steps in gene functional validation. The project also focuses on optimising this experimental procedure using seven resistance genes (*LepR1*, *Rlm3*, *Rlm2*, *LepR3*, *Rlm4*, *Rlm7*, and *Rlm9*), which will be established as the primary procedure in R gene functional analysis. This approach is expected to reduce the time required for functional gene validation. The functional validation of candidate genes via stable transformation in *B. napus* is also being explored.

The insertion of DNA into a target genome via genetic engineering technologies is a valuable tool for functionally validating and investigating R genes. This project aims to stack the five previously validated R genes (*Rlm2*, *LepR3*, *Rlm4*, *Rlm7* and *Rlm9*) into a single cultivar, exceeding the limits of conventional breeding methods, which allow only two alleles of an R gene to be present at a given time. Population genomics will reveal the evolutionary impact of such a cultivar on pathogen virulence and resistance breakdown.

This research is supported by GRDC, ARC Training Centre for PBAF, DOST-SEI and Nufarm Pty Ltd.

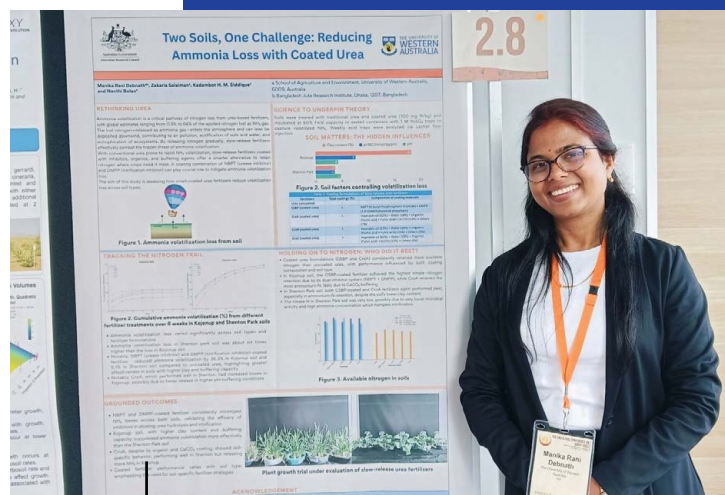


Regenerating *B. napus* epicotyl explant, 45d post-transformation, non-transgenic control.

Enhancing nitrogen nutrient delivery for sustainable crop production



PhD student Manika Rani Debnath Showcasing nitrogen use efficiency research to industry visitors from CSBP.



Best Poster Award-winning poster presented at the Second Global Conference on Sandy Soils 2025.

Project team: Professor Nanthi Bolan¹ (project leader; nanthi.bolan@uwa.edu.au), Manika Rani Debnath¹, Hackett Professor Kadambot Siddique², Associate Professor Zakaria Solaiman¹

Collaborating organisations: ¹UWA

Nitrogen (N) fertilisation is essential for crop production; however, its efficiency is often low due to significant losses through ammonia (NH₃) volatilisation and leaching. These losses reduce fertiliser effectiveness and contribute to environmental impacts. Slow-release nitrogen fertilisers (SRNFs), including those coated with inhibitors or organic materials, offer a potential strategy to improve nitrogen use efficiency (NUE). However, their performance is often soil- and crop-dependent.

This research aims to investigate the potential of SRNFs in enhancing NUE and agricultural sustainability. The study focuses on evaluating the effectiveness of SRNFs in reducing nitrogen losses as well as assessing agronomic efficiency.

During 2025, substantial progress was achieved through a series of controlled glasshouse and laboratory experiments.

A glasshouse experiment, completed in early 2025, evaluated the effects of slow-release urea fertilisers on crop biomass

production. The results showed that slow-release fertilisers significantly increased root biomass in canola compared with conventional urea, although no significant differences were observed in shoot or total biomass. In contrast, no significant biomass differences were observed in wheat between slow-release and conventional urea treatments during the ten-week experimental period.

A subsequent leaching experiment was conducted over four weeks to assess nitrogen losses. Slow-release fertilisers significantly reduced cumulative nitrogen leaching during the initial two weeks compared with urea; however, by the end of the experiment, no significant differences were observed among treatments.

The findings from an incubation study investigated ammonia volatilisation dynamics in two contrasting Western Australian soils was presented at the Second Global Conference on Sandy Soils 2025, where the work received the Best Poster Award.

A second glasshouse experiment was then conducted, in which slow-release urea fertilisers significantly increased both biomass and grain yield of wheat compared with conventional urea. Another follow-up experiment was conducted to measure

the residual effect of slow-release urea fertilisers on Maize biomass.

Overall, these findings highlight that the effectiveness of slow-release fertilisers is influenced by soil type, crop response, and temporal dynamics of nitrogen release. This research contributes to the development of more efficient fertiliser strategies tailored to specific soil conditions, supporting improved nitrogen management and environmental sustainability in agricultural systems.

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.

Dissecting the Drought Tolerance QTL on Chromosome 3B Using Wheat Near-Isogenic Lines and 90K SNP Markers

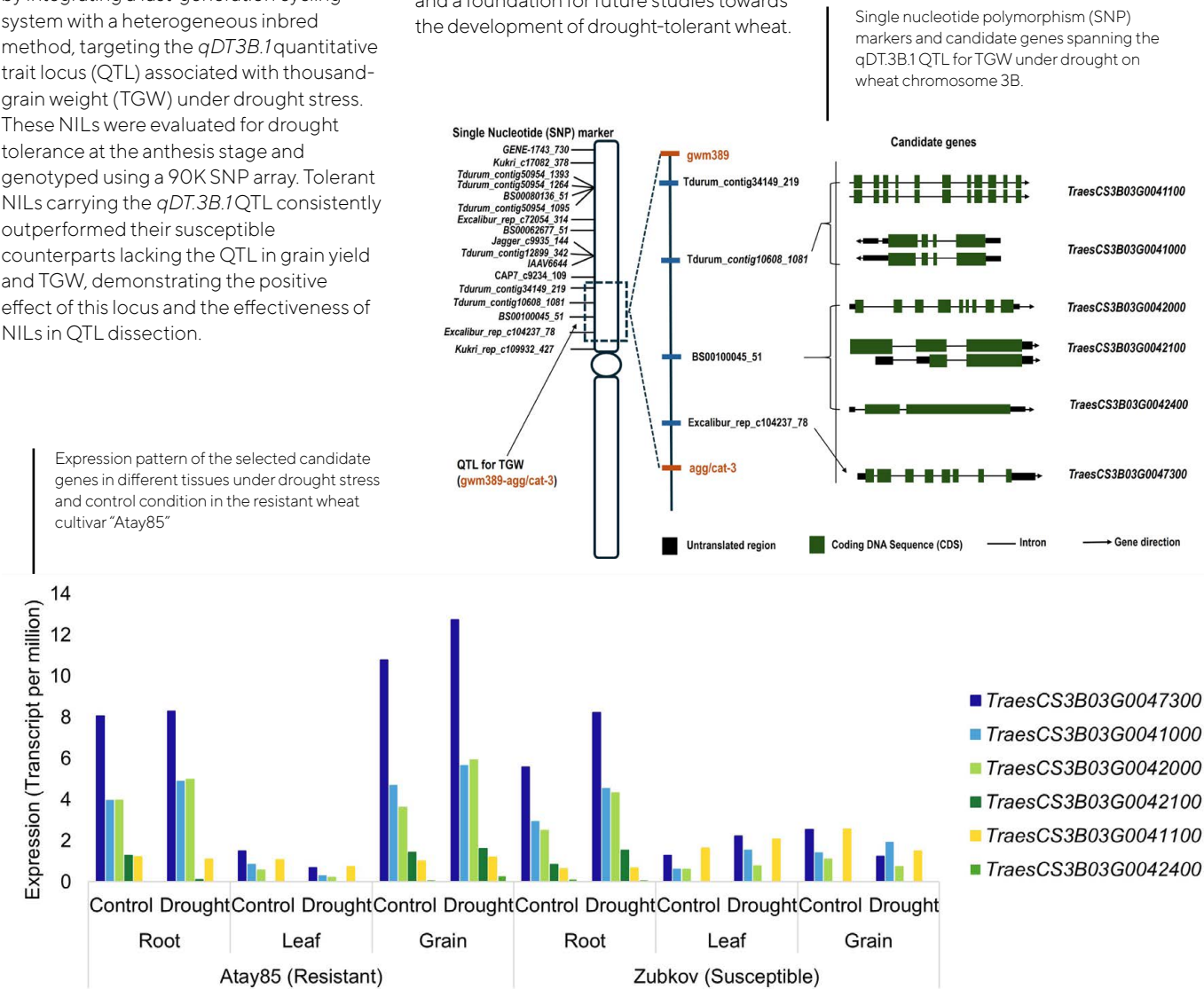
Project team: Hackett Professor Kadambot Siddique¹ (project leader; kadambot.siddique@uwa.edu.au), Joanne Caguiat^{1,2}, Professor Guijun Yan¹, Dr Sultan Mia¹, Dr Hui Liu¹

Collaborating organisations: ¹UWA; ²Philippine Rice Research Institute, Philippines

Breeding for drought-tolerant wheat varieties is one of the practical and sustainable approaches to mitigate the adverse effects of drought stress. In this study, the team accelerated the development of near-isogenic lines (NILs) by integrating a fast-generation cycling system with a heterogeneous inbred method, targeting the *qDT3B.1* quantitative trait locus (QTL) associated with thousand-grain weight (TGW) under drought stress. These NILs were evaluated for drought tolerance at the anthesis stage and genotyped using a 90K SNP array. Tolerant NILs carrying the *qDT3B.1* QTL consistently outperformed their susceptible counterparts lacking the QTL in grain yield and TGW, demonstrating the positive effect of this locus and the effectiveness of NILs in QTL dissection.

Moreover, four SNP markers were identified linked with six candidate genes, which are predicted to form an integrated network involved in assimilate transport, grain filling, plant development, and stress response. *In silico* gene expression analysis revealed that these putative candidate genes show increased expression in root and grain tissues under drought stress, suggesting their potential role in maintaining grain development. Further validation through transcriptomic analysis, fine mapping, and functional characterisation is required to confirm their functional roles. Overall, this study provides valuable genetic resources and a foundation for future studies towards the development of drought-tolerant wheat.

This research is partially supported by DISER's Global Innovation Linkage program (GIL53853), UWA, DOST-SEI and The Philippine Rice Research Institute.



Sample harvest and preparation for rhizosheath research at the UWA washing room.



Phenotype of wheat grown in monoculture and mixed with two contrasting chickpea accessions (ICC456, LC; ICC 2884, HC).



Chickpea accession-dependent rhizosheath exudates and microbes improve wheat growth under phosphorus limitation

Project team: Dr Jiayin Pang¹ (project leader; jiayin.pang@uwa.edu.au), Xiaowen Fan¹, Yunpeng Tao¹, Dr M. Asaduzzaman Prodhan¹, Hackett Professor Kadambot Siddique¹, Emeritus Professor Hans Lambers¹

Collaborating organisations: ¹UWA

Intercropping can enhance crop productivity through root exudates, arbuscular mycorrhizal fungi (AMF) and other soil microbes. However, the mechanisms enhancing wheat performance under phosphorus (P) limitation remain understood, particularly the role of intraspecific genetic variation.

Two chickpea (*Cicer arietinum*) accessions were studied: ICC456 (LC: lower carboxylate exudation, larger root system) and ICC2884 (HC: higher carboxylate exudation, smaller root system). Chickpea was grown with wheat (*Triticum aestivum*) under four belowground barriers (no barrier, 20- μ m mesh, 0.45- μ m mesh and

solid barrier) to disentangle plant-exudate-AMF-microbe interactions. An additional experiment separated chemical and biological contributions to belowground facilitation.

Wheat growth and P uptake increased when belowground interactions with chickpea were permitted. Chickpea exudates rather than AMF primarily drove facilitation, as wheat performance did not differ between 20- μ m and 0.45- μ m mesh treatments. Chickpea-derived carboxylates (e.g. malonate) were detected in wheat rhizosheath only when wheat was grown with HC under no-barrier treatment. In mixtures, HC performance was enhanced, whereas LC was suppressed relative to monoculture. Exogenous chickpea-derived root exudates and rhizosheath microbes increased wheat yield, but their combined effects were stage-dependent and non-additive.

These findings demonstrate accession-specific, exudate-mediated facilitation in wheat-chickpea mixture and provide a trait-based framework for improving resource-use efficiency in low-P agroecosystems.

This research is supported by the ARC (LP200100341), CSC, and the UWA-CSC HDr Top-Up Scholarship.

Can we optimise the way microorganisms stabilise organic amendments in soils?

Project team: Dr George Mercer¹ (project leader; George.mercer@uwa.edu.au), Dr Bede Micken^{1,2}, Associate Professor Deirdre Gleeson¹, Evonne Walker¹, Dr Christian Krohn³, Dr Christopher Buhlmann⁴, Professor Megan Ryan¹

Collaborating organisations: ¹UWA; ²Richgro Garden Products; ³RMIT; ⁴USQ; Water Corporation

In partnership with the ARC Training Centre for the Transformation of Australia's Biosolids Resource, Richgro and Water Corporation, The University of Western Australia has been developing compost and biochar amendments that return balanced ratios of carbon and nutrients from urban systems back into soils, increasing the likelihood of carbon stabilisation.

Microbial carbon use efficiency has been linked to soil carbon storage globally, but the direction of this relationship is reversed depending on the method of measurement, significantly complicating the implications for practice change.

This experimental research provides an important update to the narrative and a deep dive into the drivers of carbon use efficiency modelled from stoichiometry theory (CUEST) in agricultural soils that have been amended with compost and

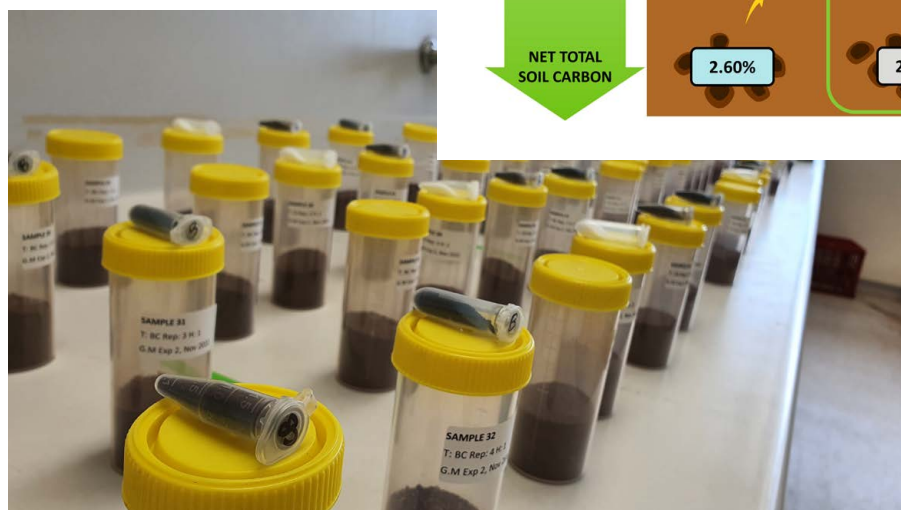
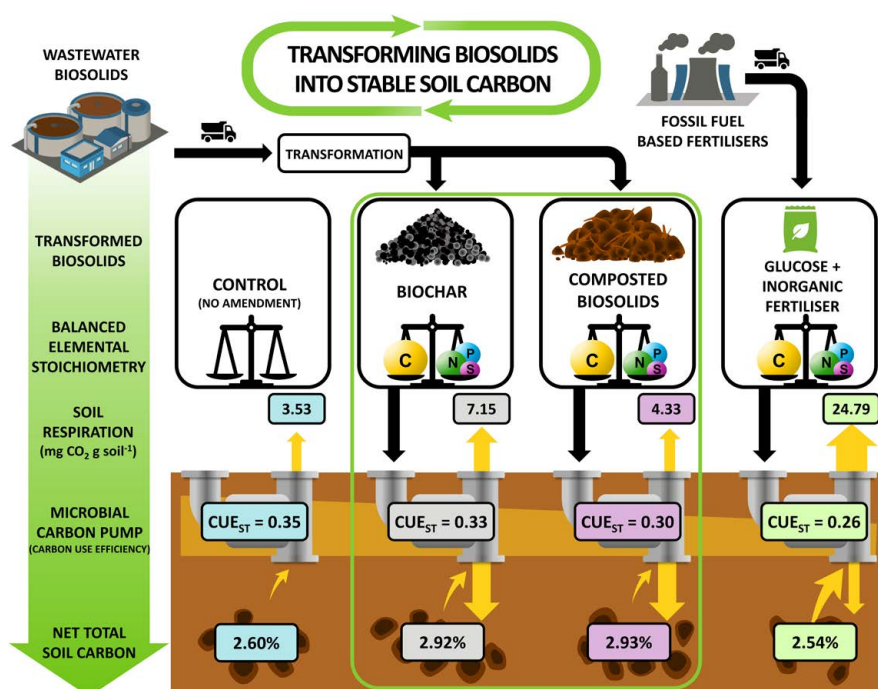
biochar. The study found that:

Stoichiometrically-balanced composted biosolids reduces the disturbance to microbial communities, minimising CO₂ evolution and increasing net soil C.

- Compost and biochar differentially increase CUE via acidification and alkalisation pathways.
- Microbes increase CUE through microbial diversity in compost and biochar amended soils.
- Enzyme-based methods convolute the relationship between CUE and C storage.

The full article is available open access in Soil Biology and Biochemistry, titled 'Probing the pump: Soil carbon dynamics, microbial carbon use efficiency and community composition in response to stoichiometrically-balanced compost and biochar'.

This research is supported by ARC Training Centre for the Transformation of Australia's Biosolids Resource, AW Howard Trust and Water Research Australia.



Soil microcosm experiment in the UWA Soil Biology Lab.

Commercial potting mixes and organic fertilisers as a potential source of antibiotic resistance elements



Investigating antibiotic resistance elements in potting mixes and organic fertilisers.

Project team: Associate Professor Zakaria Solaiman¹ (project leader; zakaria.solaiman@uwa.edu.au), Hackett Professor Kadambot Siddique¹, Professor Zed Rengel¹, Dr Sajeevee Kadawatha Dina Mithrage¹, Wafa Al-Saidi¹

Collaborating organisations: ¹UWA.

The growing use of commercialised organic amendments such as potting mixes and soil mixes in agricultural settings raises worries about their potential role in spreading antimicrobial resistance (AMR) and antibiotic resistance genes (ARGs) in agricultural lands and natural environments.

Organic fertilisers, potting, and soil mixers are commonly comprised of manure, compost, or food waste, and are high in nutrients; however, they may also contain antibiotic residues, ARGs, and resistant bacteria. These ARGs and mobile genetic

components, which are well-established in microbial communities, can survive different fertiliser production processes, particularly under poor conditions. When applied to soil, these commercialised products, especially those with high ARGs load, have the potential to contribute to the environmental resistome by increasing resistance via horizontal gene transfer and selective pressures.

This study investigates the prevalence and diversity of these genes and their major hosting bacterial phyla in commercialised organic fertilisers (compost and different manure sources) and potting mixes.

PacBio sequencing of the full-length 16S rRNA gene and Real-time quantitative PCR (qPCR) were used to estimate the abundance and diversity of ARGs and mobile genetic elements, as well as the diversity of microbial communities. The

main aims of this study are to quantify and compare ARG abundance in commercial compost, potting mix, and manures, identify microbial hosts and mobile genetic elements (MGEs) associated with ARGs and assess the impact of feedstock on ARG prevalence.

The results of the ongoing project will deepen our understanding of the link between antimicrobial use on animal farms and the dissemination of antibiotic resistance on crop farms, advise on antibiotic stewardship, especially on livestock farms, and inform soil health management and sustainable agricultural practices.

This research is supported by UWA.



Progress photo from the glasshouse experiment.

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

Project team: Associate Professor Zakaria Solaiman¹ (project leader; zakaria.solaiman@uwa.edu.au), Hackett Professor Kadambot Siddique¹, Professor Zed Rengel¹, Mostarak Hossain Munshi¹

Collaborating organisations: ¹UWA; Troforte Innovations Pty Ltd

Agricultural practices, including the use of synthetic fertilisers, herbicides, and organic amendments, can alter soil microbial communities and may contribute to the development and spread of antimicrobial resistance (AMR). This project investigates how different farming systems influence soil microbial diversity and AMR, with a focus on identifying the key drivers of differences between conventional and biological farming systems. To address this, a series of experiments has been undertaken.

In the first experiment, soil samples were collected from a pasture system in Donnybrook, Western Australia. Soil physicochemical properties, including pH, electrical conductivity, total carbon and nitrogen, and nutrient concentrations, were analysed. Microbial community composition was assessed using full-length 16S rRNA gene sequencing, followed by bioinformatic analysis to predict AMR gene abundance.

The next experiment focuses on long-term conventional and biological wheat farming systems in Western Australia. Soil sampling and physicochemical analyses have been completed; DNA has been extracted and submitted for shotgun metagenomic

sequencing to provide detailed insights into microbial diversity and AMR gene profiles. In addition, a controlled glasshouse experiment has been established to examine the individual effects of different fertilisers on microbial diversity and AMR.

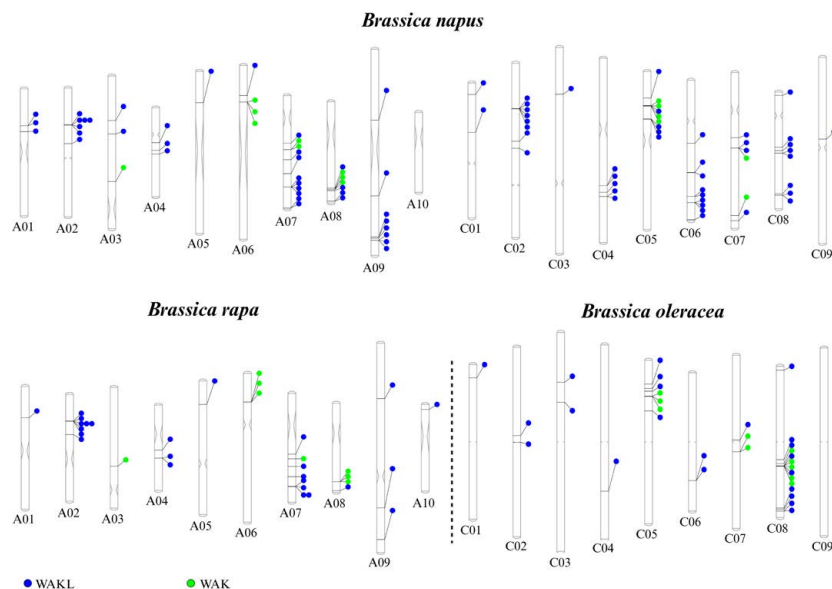
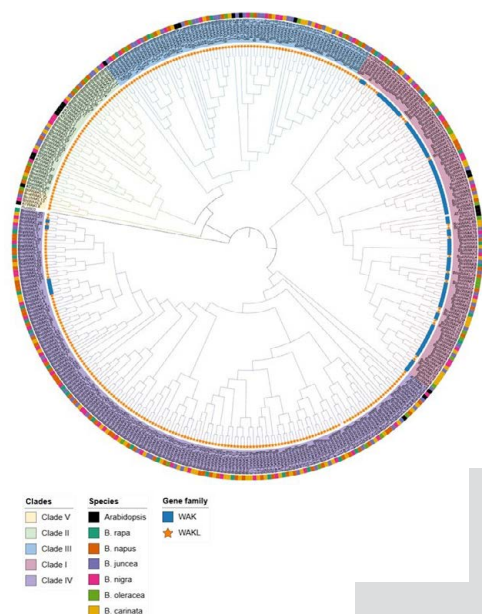
Overall, this research integrates field observations and controlled experiments to understand better how agricultural practices influences soil microbial communities and AMR, contributing to the development of more sustainable farming systems.

This research is supported by CRC - SAAFE.



Soil sampling from a wheat field.

Maximum Likelihood phylogenetic tree of WAK/WAKL proteins from six *Brassica* species within the U-triangle, along with *Arabidopsis thaliana*. Phylogenetic analysis revealed five major clades corresponding to previously described structural groups in *A. thaliana*



Chromosomal distribution of WAK and WAKL genes in *Brassica napus* following allopolyploid speciation between A (*B. rapa*) and C (*B. oleracea*) genome lineages.

Genome-wide identification and evolution of the wall-associated kinase (WAK) and wall-associated kinase-like (WAKL) gene family across the U-triangle

Project team:

Professor Jacqueline Batley¹ (project leader; jacqueline.batley@uwa.edu.au), Professor Angela van de Wouw², Dr Thomas Bergmann¹, Dr William Thomas¹, Dr Sarah Lock¹, Joao Lucas Fontana¹

Collaborating organisations:

¹UWA; ²University of Melbourne; KAYA Research Compute Platform

Resistance gene analogues (RGAs) are a diverse group of genes characterised by conserved sequence motifs and domain architectures typically associated with plant disease resistance. RGAs encompass classical disease resistance (R) genes, which confer complete, racespecific resistance, as well as quantitative resistance (QR) genes, which are polygenic and provide partial but usually long-lasting resistance. While R-gene-mediated resistance is often rapid and effective, it can be overcome by pathogen evolution. In contrast, QR is typically more durable due to the cumulative effects of multiple genes.

Broadly, RGAs include nucleotide-binding site leucine-rich repeat (NLR) proteins and transmembrane leucine-rich repeat (TMLRR) proteins, the latter of which can be subdivided into receptor-like kinases (RLKs) and receptor-like proteins (RLPs) based on the presence or absence of a cytoplasmic kinase domain.

WAKs are a small gene family within the RLKs that were first identified as a clustered group on chromosome 1 in *Arabidopsis thaliana*. These genes function as cell surface receptors that physically link the extracellular matrix to the cytoplasm. A related subfamily sharing high sequence similarity and conserved domain architecture with WAKs was later identified and named wall-associated kinase-like (WAKL).

The three allotetraploid species *Brassica juncea* (AABB, $n = 18$), *B. napus* (AACC, $n = 19$), and *B. carinata* (BBCC, $n = 17$) originated from ancient spontaneous interspecific hybridisation events among the diploid species *B. rapa* (AA, $n = 10$), *B. nigra* (BB, $n = 8$), and *B. oleracea* (CC, $n = 9$), forming the classical Triangle of U. This well-defined evolutionary framework provides an excellent system for investigating gene family evolution and divergence following polyploidisation.

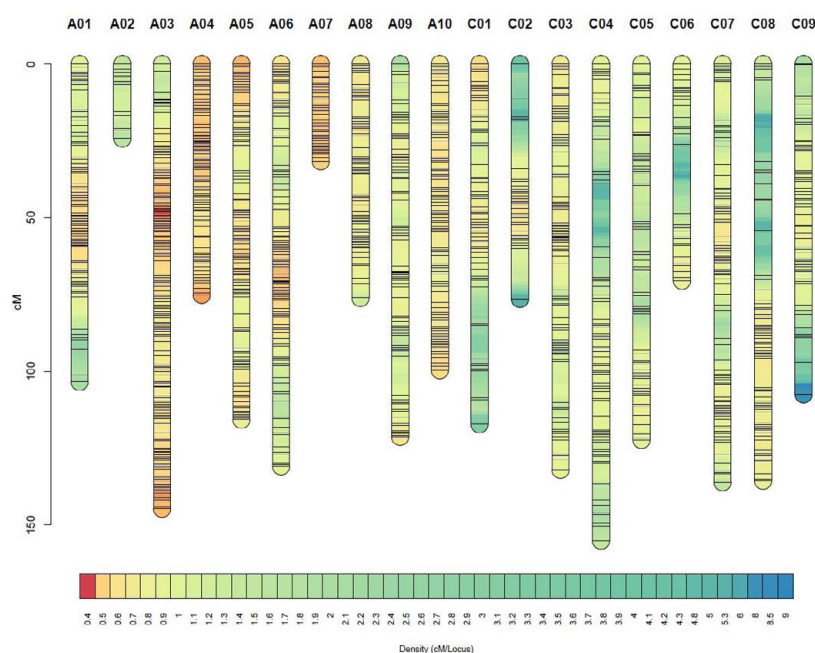
Given that WAK/WAKL genes are resistance gene analogues and are strongly associated with biotic and abiotic stress responses, they represent promising candidates for improving disease resistance. Notably, among the five cloned blackleg resistance genes in canola, three are allelic variants of the same WAKL gene. In addition, multiple WAKs have been identified and functionally characterised as resistance

genes in other plant-pathogen systems.

This study provides the first comprehensive characterisation of the WAK/WAKL gene family across the six *Brassica* species representing U's Triangle, based on high-quality reference genomes. A total of 377 WAK/WAKL genes were identified, with the allotetraploid species *B. napus*, *B. juncea*, and *B. carinata* containing substantially more family members than their diploid progenitors *B. rapa*, *B. oleracea*, and *B. nigra*. However, when compared at the subgenome level, the polyploids contained fewer WAK/WAKL genes than their respective progenitors. Across all species, WAKL genes were consistently more abundant than WAK genes, reflecting the more flexible domain architecture of WAKL proteins compared to the strictly defined structure of WAKs.

Phylogenetic analysis confirmed the conservation of five major clades originally described in *Arabidopsis*, highlighting structural diversity and potential functional specialisation within the family. Together, these resources provide a foundation for future functional studies and breeding applications, serving as a valuable tool for identifying candidate genes for disease resistance.

This research is supported by GRDC and ARC.



Genome-wide linkage map of Castle X Topas population, showing marker distribution across A and C subgenomes (A01-A10, C01-C09). Marker density (cM/locus) is illustrated by the colour gradient, with Red colours indicating higher density and Blue colours indicating lower density.



QR cotyledon assay showing inoculated canola seedlings at the cotyledon stage. The experiment was conducted to determine whether quantitative resistance (QR) can be identified during early plant development.

Identifying quantitative resistance against blackleg in canola

Project team: Professor Jacqueline Batley¹ (project leader; jacqueline.batley@uwa.edu.au), Hackett Professor Kadambot Siddique¹, Professor Angela van de Wouw², Dr Thomas Bergmann¹, Dr William Thomas¹, Dr Sarah Lock¹, Dr Sultan Mia¹, Dr Jacob Zandberg¹, Joao Lucas Fontana¹, Sanjida Akter¹, Riley Sayle¹

Collaborating organisations: ¹UWA; ²University of Melbourne; KAYA Research Compute Platform

Blackleg is a major constraint on canola production in Australia. While the deployment of major resistance (R) genes has long been a cornerstone of blackleg management, it has also imposed strong selection pressure on the pathogen, leading to the rapid evolution of more virulent *Leptosphaeria maculans* populations. As a result, many known blackleg R genes have become less effective over time, making durable disease control increasingly challenging.

This has shifted attention towards quantitative resistance (QR), which is generally more durable due to the cumulative, additive effects of multiple genes. Unlike qualitative resistance conferred by major R genes, QR is polygenic and provides partial, but usually long-lasting, resistance. However, the genetic complexity of QR has limited its characterisation in canola to date.

This project aimed to identify sources of blackleg QR using double haploid (DH) populations derived from previously identified resistant and susceptible lines, employing multiple genotyping approaches and phenotyping methods, followed by QTL mapping and the narrowing down of QTL regions to identify candidate genes and develop molecular markers for industry application.

In addition, this project seeks to understand the relationship between qualitative resistance and QR, and how R genes may influence quantitative disease resistance. Multiple QTLs associated with blackleg resistance have been identified across seven chromosomes in canola. These QTLs harbour putative candidate genes associated with plant defence, signalling, and regulatory pathways against blackleg. These putative candidate genes will be taken forward for *in silico* functional annotation. This will help predict their roles in disease resistance pathways and elucidate their expression patterns and will be followed by functional validation to assess their contribution to quantitative resistance to blackleg disease.

To complement genetic mapping approaches, this project also explores the use of RNA sequencing to characterise early molecular responses associated with QR and assess their predictive value for adult disease outcomes. Transcriptomic analyses were conducted on seedling

tissues following blackleg inoculation to capture host responses during the initial infection stages. Multivariate analysis of these data revealed strong associations between seedling-stage gene expression patterns and adult blackleg severity, indicating that key components of QR are active well before adult symptoms develop. Notably, these transcriptional signatures were identified independently of pathogen load, indicating that host regulatory processes play a key role in determining adult resistance.

Integration of RNA-seq results with proteomic data further strengthened these findings, with overlapping candidate genes identified across both molecular layers. Importantly, several QR-associated transcripts and proteins co-localised with previously identified QTL regions, providing independent genetic support for their involvement in resistance. By linking seedling molecular phenotypes with QR, this approach has the potential to accelerate breeding programs and reduce reliance on time-consuming field-based phenotyping, while simultaneously refining candidate gene identification within dense QTL regions.

This research is supported by GRDC and ARC.

Genetic dissection of phosphorus use efficiency and seed P traits in chickpea reveals targets for low-P adaptation

Project team: Dr Jiayin Pang¹ (project leader; Jiayin.pang@uwa.edu.au), Huaikang Jing¹, Associate Professor Peta Clode¹, Emeritus Professor Hans Lambers¹, Hackett Professor Kadambot Siddique¹

Collaborating organisations: ¹UWA; Murdoch University

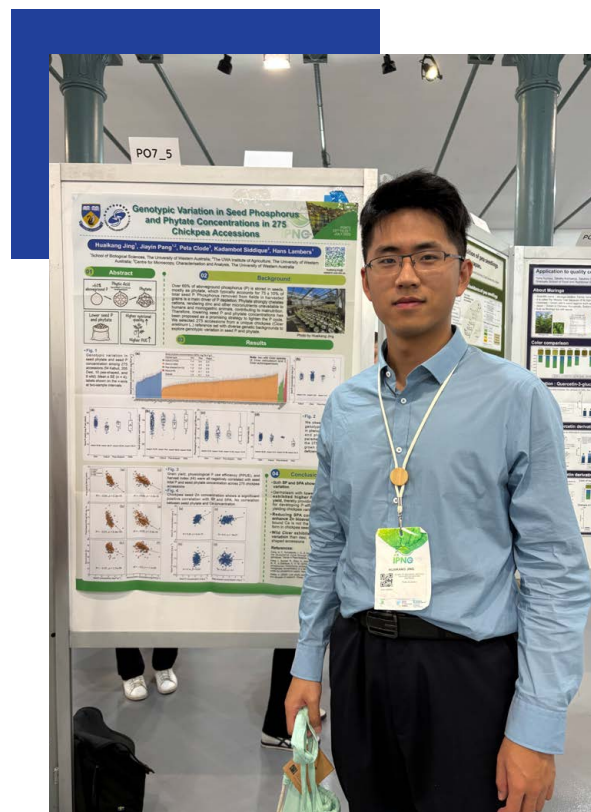
Phosphorus (P) is an essential macronutrient required for plant growth, serving as a key structural component of nucleic acids, proteins, and cellular membranes. Notably, more than 60 per cent of aboveground P is ultimately allocated to seeds, making grain P removal a major pathway of P loss from agricultural systems. Reducing seed P concentration therefore represents a promising strategy to minimise P export from cropping systems and decrease reliance on phosphate fertilisers, contributing to more sustainable agricultural practices.

In seeds, phosphorus is predominantly stored as phytate which typically accounts for approximately 75 per cent of total seed P. Phytate forms complexes with mineral cations such as K, Mg, Ca, Zn, and Fe, significantly reducing their bioavailability and contributing to micronutrient deficiencies in human and animal diets. Therefore, improving crop P-use efficiency while reducing seed P and phytate concentrations is an important goal for both agricultural sustainability and nutritional quality. However, the genetic and physiological mechanisms regulating seed P accumulation, particularly in legumes such as chickpea, remain poorly understood.

Chickpea (*Cicer arietinum* L.) is the third most widely cultivated legume crop globally and serves as an important source of plant-based protein. In this study, a diverse panel of 275 chickpea accessions were evaluated under phosphorus-limited conditions to investigate phenotypic variation in agronomic and P-related traits. By integrating high-density genotypic data, a genome-wide association study (GWAS) was performed to identify loci associated with seed phosphorus and phytate traits.

This study achieved four main objectives. First, a substantial phenotypic variation in chickpea was characterised under low-P conditions, highlighting significant genetic potential for improving P-use efficiency. Second, the relationships among key agronomic and P-related traits were analysed, revealing coordinated trait patterns under nutrient limitation. Third, GWAS analysis identified significant genomic regions and candidate genes associated with seed P and phytate accumulation. Finally, haplotype analysis further resolved favourable allelic combinations at candidate loci, providing insights into their functional relevance.

Overall, this study enhances our understanding of the genetic architecture underlying phosphorus use efficiency and seed P allocation in chickpea. The identification of favourable haplotypes and candidate genes provides valuable targets for breeding programs aimed at developing high-yielding, P-efficient chickpea varieties with improved nutritional quality under low-P conditions.



PhD student Huaikang Jing presenting the research at the 2025 IPNC.

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



Chickpea accessions screening work.

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

Project team: Professor Nanthi Bolan¹, (project leader; nanthi.bolan@uwa.edu.au), Hackett Professor Kadambot Siddique¹, Associate Professor Zakaria Solaiman¹, Zahra Nizbat¹

Collaborating organisations: ¹UWA

Cropping systems in sandy soils, particularly in Western Australia, are constrained by low soil organic carbon (SOC), poor nutrient retention, and high susceptibility to nitrogen (N) losses. While organic amendments such as compost are increasingly used to improve soil fertility, their benefits are often short-lived due to rapid mineralisation, leading to inefficient nutrient use and increased greenhouse gas (GHG) emissions. This project examined whether clay-induced stabilisation of organic carbon (C) during biowaste processing can improve SOC persistence, nutrient-use efficiency, and crop productivity within sandy cropping systems.

The research aimed to: (i) determine how clay minerals (bentonite and kaolinite) stabilise organic carbon during composting; (ii) evaluate whether clay-stabilised composts enhance soil C retention and regulate C-N dynamics

without compromising fertilisation value; (iii) assess impacts on crop productivity, nutrient uptake, and microbial function; and (iv) investigate interactions between clay amendments and nitrification inhibition (dicyandiamide, DCD) within soil systems.

Key outcomes from 2025 showed that clay amendments significantly reduced dissolved organic carbon (DOC) during composting, indicating enhanced stabilisation prior to soil application. In soil, clay-amended composts reduced CO₂ emissions, stabilised microbial biomass, improved carbon use efficiency, and enhanced ammonium (NH₄⁺) retention while suppressing nitrate (NO₃) accumulation and nitrous oxide (N₂O) emissions. These changes contributed to improved nutrient synchrony and reduced loss pathways. In the glasshouse trial, compost application significantly increased wheat biomass, grain yield, and nutrient uptake, with kaolinite-amended chicken manure delivering the strongest agronomic performance. Microbial analyses indicated shifts toward functional pathways

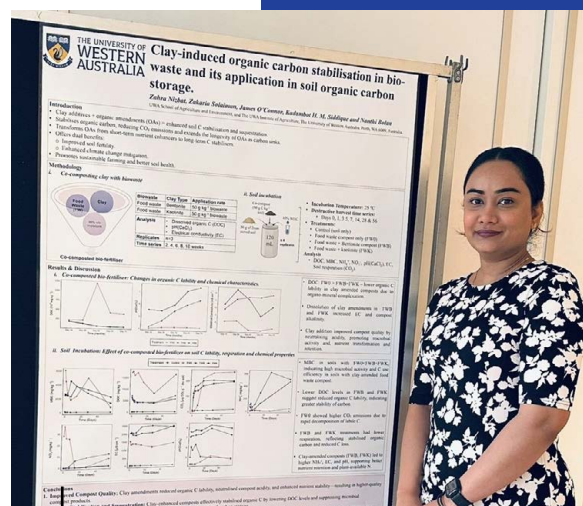
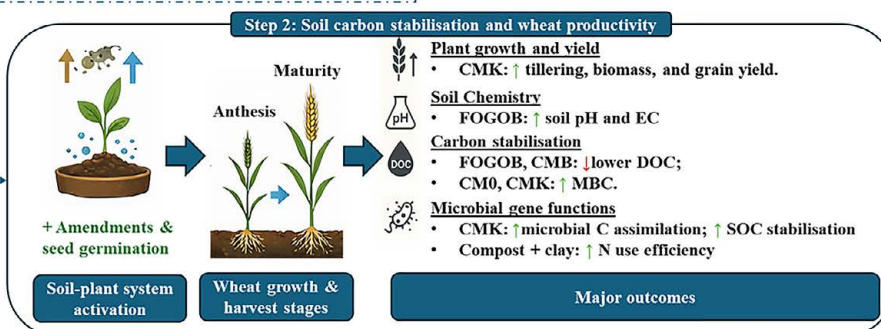
associated with carbon assimilation and improved nutrient cycling. In contrast, DCD showed only short-term effects on nitrogen dynamics, highlighting limitations of chemical inhibitors under sandy soil conditions.

In summary, this project demonstrated that integrating clay-stabilised biowastes into cropping systems can enhance SOC persistence, improve nutrient-use efficiency, and increase crop productivity while reducing environmental losses. This approach provides a practical pathway for developing more resilient and climate-smart management strategies for sandy agricultural soils.

This research is supported by UWA and DAFF's National Soil Strategy.



From biowaste to wheat: clay-stabilised composts enhance carbon retention, regulate C-N cycling, and boost productivity in sandy soils.



PhD candidate Zahra Nizbat presenting her research findings at the Sandy Soils Conference in Perth.



Glasshouse experiment for the project.



Soil-based glasshouse bioassay for seed germination.

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

Project team: Associate Professor Zakaria Solaiman¹ (project leader; zakaria.solaiman@uwa.edu.au), Hackett Professor Kadambot Siddique¹, Gokhan Karadeli¹

Collaborating organisations:¹UWA; ²CRC SAAFE

Antibiotic resistance is a surging threat to human health, imposing a growing economic burden. Since the discovery of penicillin by Alexander Fleming, antibiotics have revolutionised both human and animal health by effectively treating diseases. He warned in his 1945 Nobel Prize Speech that *“The time may come when anyone in the shops can buy penicillin. Then there is the danger that the ignorant man may easily underdose himself and by exposing his microbes to non-lethal quantities of the drug make them resistant”*. His warning also remains highly relevant in today’s livestock industry.

The widespread and inappropriate use of veterinary antibiotics to prevent diseases is a key contributor to the emergence of antibiotic resistance in livestock farms.

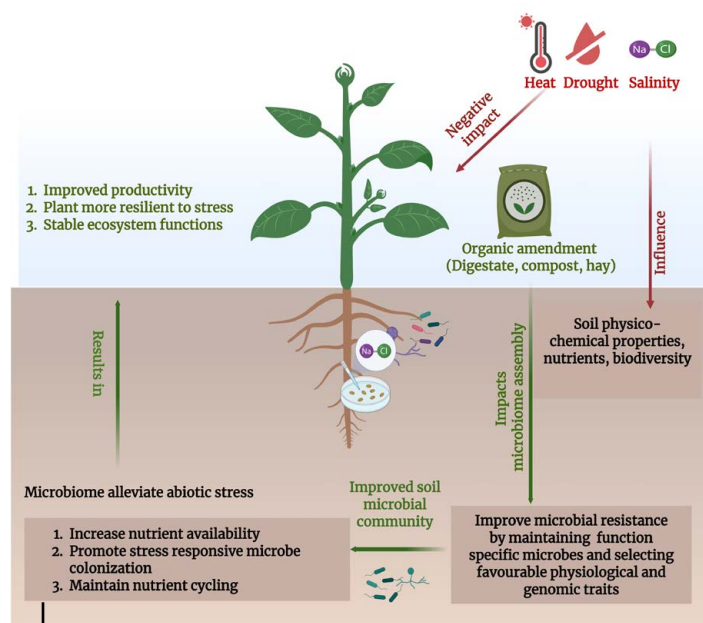
Although manure application is effective for sustainable agriculture, raw manure may pose risks by the dissemination of antibiotic-resistant bacteria (ARB) and antibiotic resistance genes (ARGs) in horticultural systems. Manure-borne ARGs can be taken up by horticultural crops and may be transferred to humans through the food chain, aggravating the risk of antibiotic resistance to human health. While manure composting mitigates antibiotic resistance, ARB and ARGs can persist in composted manure. Therefore, developing novel manure management practices is crucial to tackling this challenge before soil application within the One Health approach.

For the preliminary experiment, samples of raw and composted cow manure were collected from a cattle farm. Bacterial community diversity and abundance were analysed using PacBio full-length 16S rRNA sequencing and used PICRUST2 to predict ARG abundance and establish a baseline profile. Following the preliminary study, a laboratory-scale composting experiment was conducted, incorporating oil mallee biochar into raw cow manure

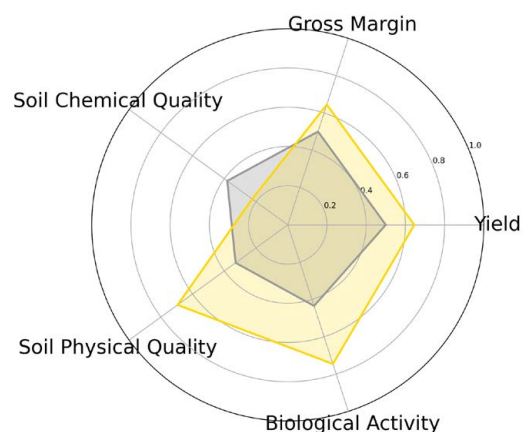
and incubating the mixtures at different ambient temperatures. Then, raw and composted manures will be applied to the soil. A soil-based glasshouse bioassay was conducted to assess tomato seed germination and early seedling growth, followed by a glasshouse experiment to evaluate the presence of ARGs in manure and the route to soil and to tomato plants. Selected ARGs are currently being quantified using quantitative polymerase chain reaction (qPCR).

The findings will provide insight into how to mitigate the risk of manure-derived antibiotic resistance genes in the agricultural environment.

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



Examples of processes investigated to understand mechanisms underpinning the impacts of biological amendments on the relative contributions of bacteria and fungi to carbon and nutrient cycling in soil. Image: Pankaj Singh



T1: Fertilizer only; T2: Compost + Fertilizer

Radar chart comparing conventional fertiliser application rate (T1, grey) and a combination of low-rate fertiliser and compost (T2, yellow) on soil biological parameters (microbial biomass carbon, fungal and bacterial gene abundance), chemical parameters (mineral nitrogen, phosphorus, potassium, pH) physical parameters (bulk density, volumetric water), yield and gross margin. Image: Hira Shaukat.

Soil biological amendments for soil health and crop performance

Project team: Dr Sasha Jenkins¹ (co-project leader; sasha.jenkins@uwa.edu.au), Emerita Professor Lynette Abbott¹ (co-project leader; lynette.Abbott@uwa.edu.au), Dr Bede Mickan¹, Professor Nanthi Bolan¹, Hackett Professor Kadambot Siddique¹, Associate Professor Zakaria Solaiman¹, Professor Marit Kragt¹, Distinguished Professor Brajesh Singh², Dr Juntao Wang², Dr Han Weng³, Muhammad Kamran³, Dr Hira Shaukat¹, Dr Thi Hoang Ha Truong¹, Dr Yunyun (Allie) Zheng¹, Dr Pankaj Singh¹, Dr Sun Kumar Gurung¹, Dr James O'Connor¹, Dr Manish Sharma¹, Ian Waite¹, Richard Ang¹, Linda Limongi¹, Zahra Nizbat¹

Collaborating organisations:¹UWA, ²Western Sydney University; ³Adelaide University; DPIRD; Richgro Garden Products; C-Wise, The Carbon Company

Improving soil health through biological amendments has attracted considerable interest, yet many claim that the evidence for broadacre farming systems is inadequate. This project used an interdisciplinary approach to quantify the impacts of biological products on soil biology and nutrient cycling and to identify the modes of action and mechanisms involved, including those observed when used in combination with chemical fertilisers. The project also demonstrated the repurposing of organic waste into beneficial residual products for improving soil health and resilience. Field, glasshouse and laboratory assays were used to identify how biological amendments can complement mineral fertilisers to enhance processes associated with nutrient cycling in soil. Molecular indicators of soil health that measure soil functionality at different scales were investigated.

The central finding is that the effects of biological amendments on soil processes are not simply additive, but are co-regulated through interacting biological, chemical and structural dimensions. For example, soils amended with digestate-loaded biochar and compost were consistently low greenhouse gas emitters. They acted as meaningful methane sinks, an environmentally significant outcome given increasing regulatory scrutiny of agricultural emissions. Clay amendments, including bentonite and kaolinite, further improved compost quality by stabilising carbon, conserving nitrogen, and optimising physicochemical properties, supporting their integration as low-cost, sustainable additives aligned with circular economy goals.

The extent to which biological amendments can mitigate the negative and increasingly severe effects of seasonal drought conditions on plant growth and biological nutrient cycling was addressed in a range of experiments. The intensity of rewetting events (seasonal droughts) determines the fate of nitrogen availability for plants and leaching loss. Therefore, slow-release amendments and their timing of application relative to seasonal drought may be a better fit for translating biological fertility investment into agronomic return. Data on soil biology was used to recalibrate and expand existing models and to identify systematic and predictable patterns for guidance on carbon storage and economic application of specific amendments to soils.

Simulations revealed that applying the same amendment at the same rate across different soil types yields responses that

depend on the soil's structural stability threshold. Soils with high microbial biomass turnover under amendments might not reflect long-term carbon storage. The impacts of various kinds of biological amendments on soil processes and soil health are complex. They do not arise from simple additive responses of independent interactions. The disconnect between microbial stimulation and agronomic performance, combined with unexpected GHG emission patterns, highlights the conclusion that soil health interventions require systems-level evaluation rather than single-parameter optimisation.

The adoption of soil biological amendments can have both short-term and long-term benefits. Longer-term benefits are needed based on the economics of whole-farm production systems. Longer-term studies demonstrate both quantitative and qualitative relationships between soil health and agricultural productivity. Incorporating the cost of off-farm waste management, as well as the cost of managing soil biological processes, into farm accounting practices is essential for establishing and maintaining healthy agricultural soils and for food security.

This research was supported by the Soil Science Challenge Grants Program funded by DAFF (project No. 4-H4T24R2) and contributes towards the National Soil Strategy and the implementation of the National Soil Action Plan.



Glasshouse-based evaluation of granulated FOGO compost in wheat at The University of Western Australia.
From left: Professor Nanthi Bolan, Jaishankar Nagarajan, Hackett Professor Kadambot Siddique and Dr James O'Connor.

Agronomic and soil health benefits of granulated Food Organics and Garden Organics (FOGO) compost as a soil amendment in wheat

Project team: Hackett Professor Kadambot Siddique¹ (project leader; kadambot.siddique@uwa.edu.au), Professor Nanthi Bolan¹, Dr Sasha Jenkins¹, Dr James O'Connor¹, Jaishankar Nagarajan¹

Collaborating organisations: ¹UWA; Green Ag Technologies Pty Ltd

Wheat production systems in Western Australia depend heavily on synthetic nitrogen (N) fertilisers, particularly urea, to sustain crop productivity and meet increasing global food demand. While effective in enhancing yields, excessive reliance on urea fertilisation has raised major environmental concerns, including ammonia (NH₃) volatilisation, nitrous oxide (N₂O) emissions, and nitrate (NO₃) leaching. These processes not only reduce nitrogen use efficiency (NUE) but also contribute to greenhouse gas emissions and water contamination. At the same time, rapid urbanisation has resulted in increasing volumes of food organics and garden organics (FOGO) waste generated through municipal waste streams. Composting this organic waste presents a valuable opportunity to recycle nutrients back into agricultural systems while diverting waste from landfill and supporting circular economy principles. Granulated FOGO compost products have recently been developed to improve nutrient uniformity, handling, and field applicability compared with traditional composts. However, scientific evidence comparing

the agronomic and environmental performance of granulated FOGO compost with conventional synthetic fertilisers in Australian wheat systems remains limited.

The overall aim of this research is to evaluate the agronomic effectiveness and environmental implications of granulated FOGO compost as an alternative or complementary N source in wheat production systems. The study investigates how FOGO compost influences soil N dynamics, wheat growth and productivity, and environmental N losses relative to urea fertiliser. The research focuses on determining optimal application rates of granulated FOGO compost, assessing its effects on N availability and plant uptake, and quantifying N loss pathways including NH₃ volatilisation, N₂O emissions, and NO₃ and ammonium (NH₄⁺) leaching under controlled experimental conditions.

Over the past year, substantial progress has been made in implementing the experimental framework. A controlled glasshouse experiment using wheat (*Triticum aestivum* L. cv. Scepter) has been completed using Cunderdin soil to compare granulated FOGO compost and urea at equivalent N application rates (75 kg N ha⁻¹ and 150 kg N ha⁻¹). The experiment was conducted using a completely randomised design with four replications to evaluate plant growth parameters, nutrient uptake, and soil chemical and biological properties at different growth stages. Measurements

included plant biomass, tiller number, root development, grain yield, and key soil indicators such as pH, electrical conductivity (EC), total carbon and N, and microbial biomass.

The outcomes of this research are expected to provide important insights into the role of recycled organic fertilisers in sustainable cropping systems. Granulated FOGO compost has the potential to improve soil health by increasing soil organic carbon, enhancing microbial activity, and improving soil structure and water-holding capacity. In addition, its slow-release N characteristics may reduce N losses through volatilisation and leaching compared with conventional fertilisers. By integrating waste-derived organic amendments into wheat production systems, this research contributes to the development of circular nutrient management strategies that reduce dependence on energy-intensive synthetic fertilisers while maintaining crop productivity. The findings will provide scientific evidence to support the adoption of recycled organic fertilisers in Australian agriculture and contribute to improving the environmental sustainability and resilience of wheat-based farming systems.

This research is supported by self-funded HDR student at UWA.

Atrazine constrains fungal conidial germination and morphological transformation to reduce the severity of the white leaf spot disease in atrazine-tolerant canola

Project team: Professor Martin Barbetti¹ (project leader; martin.barbetti@uwa.edu.au), Dr Yan Ai¹, Dr Ming Pei You¹, Dr Guijun Yan¹

Collaborating organisations: ¹UWA

To better manage weed issues in canola crops, open-pollinated atrazine-tolerant types, also known as triazine-tolerant (TT) varieties, have been widely adopted across the Australian canola industry. White leaf spot (*Neopseudocercospora capsellae*) poses a significant disease threat to canola production globally and particularly in Australia.

Studies emphasised how atrazine application reduces white leaf spot disease severity, rate and extent of conidial germination and subsequent morphological transformation into single-celled blastospores but increases collapse of conidia. Notably, in the absence of atrazine, conidial infection resulted in greater disease severity as compared

with hyphal infection and this increase in disease severity was strongly associated with more extensive morphological transformation of germinating conidia into single-celled blastospores.

Studies highlighted, for the first time, how formation of single-celled blastospores through morphological transformation is a critical determining factor not only for the comparative pathogenicity differences between conidial versus hyphal infection, but the significance of this morphological transformation in the pathogenesis of *N. capsellae* and consequent disease severity.

These findings provide new understanding of atrazine-pathogen interactions and have laid the foundation for future studies and opportunities to further explore potential dimorphism-targeted fungicidal strategies. They also provide a foundational model system for better exploring and understanding herbicide-pathogen interactions.

This research is supported by UWA.

Typical white leaf spot (*Neopseudocercospora capsellae*) leaf symptoms.



Typical white leaf spot (*Neopseudocercospora capsellae*) leaf symptoms.

Glyphosate stimulates white leaf spot disease by inducing morphological transformation in glyphosate-tolerant canola

Project team: Professor Martin Barbetti¹ (project leader; martin.barbetti@uwa.edu.au), Dr Yan Ai¹, Dr Ming Pei You¹, Dr Guijun Yan¹

Collaborating organisations: ¹UWA

Studies were undertaken to determine the effect of glyphosate application on white leaf spot (*Neopseudocercospora capsellae*) epidemics in glyphosate-tolerant (RR) canola.

Glyphosate application increased the severity of white leaf spot disease. It stimulated *N. capsellae* conidial and hyphal morphological transformation into yeast-like, single-celled blastospores but suppressed conidial germination and germ-tube extension. There was a strong association of morphological transformation with the extent of leaf yellowing.

Notably, increased blastospore formation from glyphosate application appears to be a key driver for the success of both conidial and hyphal infections. It likely provides an alternative pathway that enhances *N. capsellae* infection and disease development in the presence of glyphosate. Moreover, the increased leaf yellowing observed with glyphosate alone suggests that glyphosate can directly facilitate plant senescence, which also favours disease.

These findings provide a new mechanistic understanding of the interaction between glyphosate, *N. capsellae* and the host plant, and also opens the way for using this system as a herbicide-pathogen-host plant model to explore the strategic use of recommended glyphosate application in managing dimorphic fungal diseases in glyphosate-tolerant canola and other herbicide-tolerant crops.

This research is supported by UWA.

Monitoring plant water use in a controlled environment using custom-built sap flow sensors on the stem top and base.

Comparative analysis of diurnal water use dynamics in two halophytic shrubs under non-saline and saline conditions



Project team: Professor Erik Veneklaas¹ (project leader; erik.veneklaas@uwa.edu.au), Gaku Sagara², Associate Professor Yoshiyuki Miyazawa³, Associate Professor Sugiura Daisuke²

Collaborating organisations: ¹UWA; ²Nagoya University, Japan; ³University of the Ryukyus, Japan

In southwestern Australia, forage shrubs that tolerate salinity and drought may provide feed in dry summers and autumns. Perennial halophytic shrubs such as *Atriplex nummularia* (C4) and *Rhagodia preissii* (C3) can play an important role in farming systems. The physiological mechanisms underlying their tolerance of drought and salinity are not fully understood. This study focused on two traits that may contribute to their stress tolerance: (1) the ability to close and open stomata rapidly and (2) the role of stored stem water in buffering diurnal transpiration.

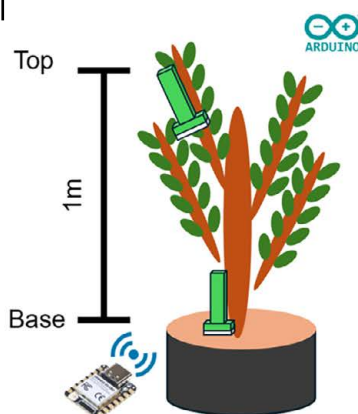
Experiments were conducted in a growth room with controlled temperature, humidity and light conditions at the University of Western Australia in 2024 using pot-grown plants under non-saline and saline (250 mM NaCl) conditions. Stomatal conductance under both conditions was measured and evaluated at the speed of stomatal closure to fluctuating light environments using portable gas exchange systems. To evaluate the dynamics of stored water in shrubs, a non-invasive small sap flow sensor was developed and utilised based on the Heat Ratio Method (HRM), controlled by Arduino-based microcontrollers. Sap flow was measured at both the stem base and the upper shoot, and it was investigated whether a time lag between the positions was caused by the use of stored water. The team also determined capacitance, defined as the change in water content per unit change in tissue water potential, to further quantify the capacity to store and release water under non-saline and saline conditions.

The findings indicate that both species adopt a conservative water-saving strategy with rapid stomatal closure during dark periods to minimise unnecessary water loss. A significant discovery was the delay in sap flow increase at the stem base following light transitions, particularly in *Rhagodia* under non-saline conditions. This delay suggests a reliance on stored water within the shoot to support transpiration. Notably, the estimated contribution of stored water to total daily transpiration was higher under salt stress in both species, and capacitance increased.

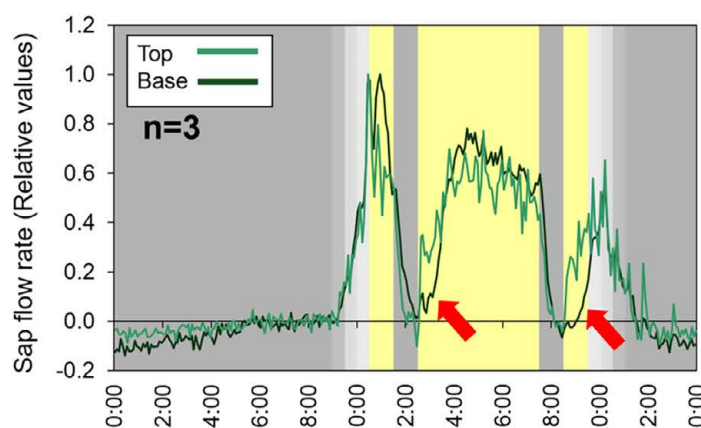
The successful implementation of non-invasive sap flow sensors in this study provides a new methodology for investigating the water use dynamics in halophytic shrubs. These findings enhance the mechanistic understanding of how halophytic shrubs coordinate stomatal regulation and internal hydraulics to survive in dry and saline environments.

This research is supported by Professor Veneklaas' discretionary funding, and Dr Hayley Norman, CSIRO, kindly provided plants.

Diurnal sap flow dynamics at the stem top and base of *Rhagodia preissii* under non-saline conditions, illustrating the temporal lag in water movement at the base.



Rhagodia (Non-saline)





A flock of sheep at UWA Farm Ridgefield.

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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Gut microbial genetic variations are associated with exploratory behavior via SNV-driven metabolic regulation in a sheep model

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Collaborating organisations: ¹UWA; ²Nanjing Medical University, China

Neurocognitive function plays a fundamental role in animal behavior, welfare, and productivity, yet the biological mechanisms underpinning individual variation remain poorly understood. Increasing evidence highlights the gut-brain axis as a key regulatory pathway linking the gut microbiome to host cognition and behavior. However, most studies focus on microbial species abundance and overlook strain-level genetic variation, which may drive functional heterogeneity. This project aimed to investigate how gut microbial genetic variation – specifically single nucleotide variations (SNVs) – influences host metabolism and exploratory behavior using a Merino sheep model.

Multi-omics data from 200 juvenile Merino sheep were integrated, including metagenomic sequencing of fecal and rumen samples, untargeted plasma metabolomics (953 metabolites), and 21 neurobehavioral phenotypes related to stress response, learning, and exploration. The team successfully constructed the largest sheep gut microbiome genome resource to date, generating 27,223 metagenome-assembled genomes (MAGs) and identifying 5,253 non-redundant species-level genomes, of which 3,628 represent potentially novel species. From these genomes, 146 million microbial SNVs were identified, enabling high-resolution strain-level analyses.

Association analyses revealed that within-species microbial genetic dissimilarity was significantly associated with host neurobehavioral traits. Notably, phylogenetic differences in 85 per cent of prevalent species were linked to exploratory behavior in a novel-object

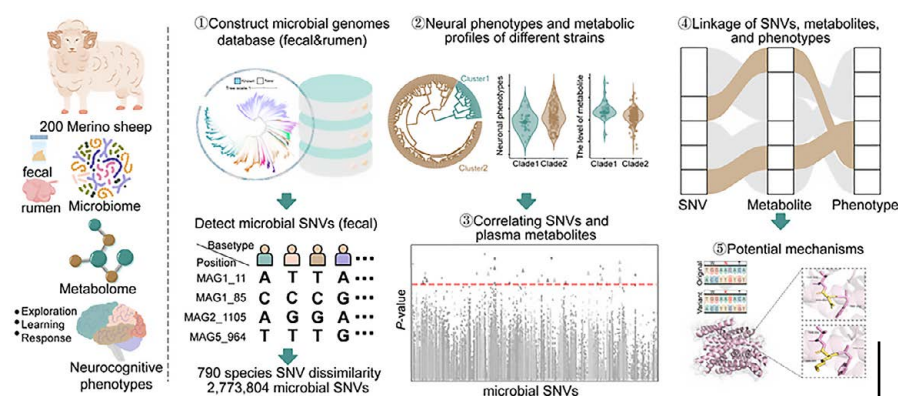
arena test. The team further identified 35 study-wide significant associations between microbial SNVs and plasma metabolites, many of which were enriched for neuroactive and oxidative stress-related pathways. For example, SNVs in a novel species were associated with variation in 4-anisic acid and D-galacturonate – metabolites implicated in BDNF biosynthesis and neuronal protection. Integrated analyses demonstrated that specific microbial SNVs may modulate exploratory behavior through structural changes in encoded proteins that influence metabolite production and transport.

This project provides the first strain-level, multi-omics evidence that microbial genetic variation contributes to host neurocognitive traits via metabolic regulation. By moving beyond species-level profiling to single nucleotide resolution, the study advances understanding of microbiome-driven functional diversity. The findings have dual significance: (1) establishing a mechanistic framework for microbiome-neurocognition interactions relevant to neurometabolic disorders, and (2) informing precision livestock breeding and health management strategies targeting microbiome functionality. The genomic resources and analytical framework that have been developed, represent a valuable foundation for future microbiome-based interventions in both animal and translational biomedical research.

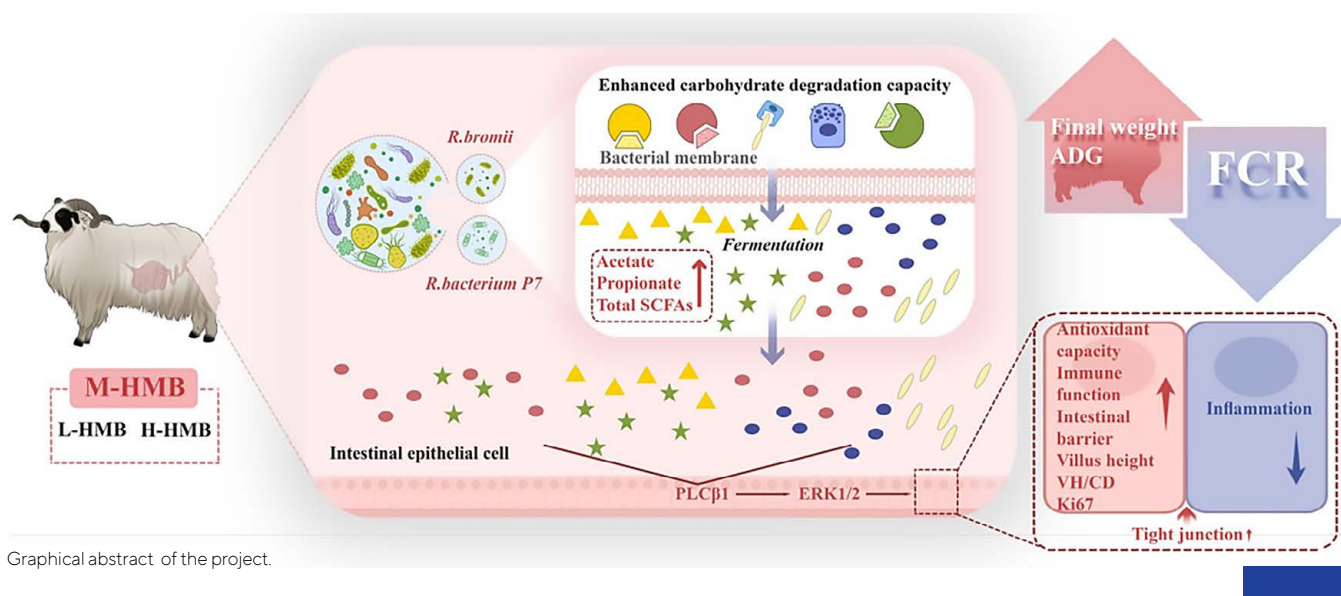
This research is supported by Natural Science Foundation of the Jiangsu Higher Education Institutions of China (BK20250888) and The UWA Institute of Advanced Studies Visiting Fellowship.



A follow-up study by Dr Luoyang Ding testing whether early rumen microbiome inoculation influences animal behaviour.



Overview of study cohorts and analysis workflow.



Dietary β -hydroxy- β -methyl-butyrate supplementation improves intestinal health and growth performance in Tibetan sheep lambs via modulating small intestinal microbiota

Project team: Shengzhen Hou³ (project leader, qhdxhsz@163.com), Yangchun Cao^{2,3} (project leader, caoyangchun@126.com), Jieqiong Cai^{2,3}, Weibin Wu², Lamei Wang², Dandan Meng², Hao Yang², Dr Shimin Liu¹

Collaborating organisations: ¹UWA;

²Northwest A&F University, China;

³Qinghai University, China

Tibetan sheep grazing on the Qinghai-Tibet Plateau require dietary protein supplementation; however, they face economic constraints due to the high cost of feed transportation in this region. Given that the leucine metabolite β -hydroxy- β -methyl butyrate (HMB) enhances both protein synthesis and intestinal nutrient absorption, this study employed metagenomics and untargeted metabolomics to systematically evaluate HMB's effects on antioxidant capacity, immune response, microbiota, metabolites, and the health of the small intestine in Tibetan sheep. A total of 120 healthy weaned 60-day-old male Tibetan lambs were assigned to diets containing 0 mg/kg (control group, CON), 430 mg/kg (low HMB, L-HMB), 715 mg/kg (medium HMB, M-HMB), or 1,000 mg/kg (high HMB, H-HMB) for 90 d. At the end of the experiment, 6 lambs from each group were slaughtered for intestinal tissue and content sampling.

The M-HMB treatment significantly increased average daily gain of the lambs without affecting feed intake, thereby improving feed utilization efficiency. M-HMB promoted the development of small intestinal morphological and elevated villus height, while also enhancing the activities of digestive enzyme and disaccharidase activities. Furthermore, M-HMB enhanced the antioxidant capacity, immune response, and barrier function of the small intestine. Metagenomic analysis revealed M-HMB supplementation improved the composition of the small intestinal microbiota in Tibetan sheep, specifically increasing the relative abundance of *Ruminococcus bacterium P7* and *R. bromii*, and enhanced microbial carbohydrate degradation capacity. Metabolomic analysis demonstrated that M-HMB supplementation significantly altered the small intestinal metabolite profile, enhancing carbohydrate metabolic pathways and increased the production of short-chain fatty acids (SCFAs). M-HMB upregulated PLC β 1 and ERK1/2 protein expression levels in small intestinal tissue and elevated the proportion of Ki67-positive cells at the basal crypt region of small intestinal crypts, suggesting enhanced proliferative activity of intestinal epithelial cells.

In summary, dietary supplementation with M-HMB (715 mg/kg) promoted small intestinal growth and development, enhanced digestive and absorptive functions, optimized the microbial composition, improved carbohydrate degradation, and increased the production of SCFAs, ultimately improving the growth performance of Tibetan sheep lambs.

This research is supported by the Fund of Key Laboratory of Qinghai-Tibet Plateau Grazing Yak and Tibetan Sheep Animal Nutrition and Feed-Forage, Ministry of Agriculture and Rural Affairs, P. R. China (2025-YYKF-03) and Construction of Standardized Production System for Improving quality and efficiency of Tibetan sheep industry (2022-NK-169).

A multifunctional probiotic co-delivery platform for the treatment of *Clostridium difficile* infection

Project team: Xinhua Chen³ (project leader; xchen1@bidmc.harvard.edu), Yangchun Cao^{2,3} (project leader; caoyangchun@126.com), Hao Yang², Yanling Kuang², Lamei Wang^{2,3}, Huimin Zhang², Rui Zhang², Yanfei Dai², Javier Villafuerte Galvez³, Junhu Yao², Dr Shimin Liu¹

Collaborating organisations: ¹UWA;

²Northwest A&F University, China;

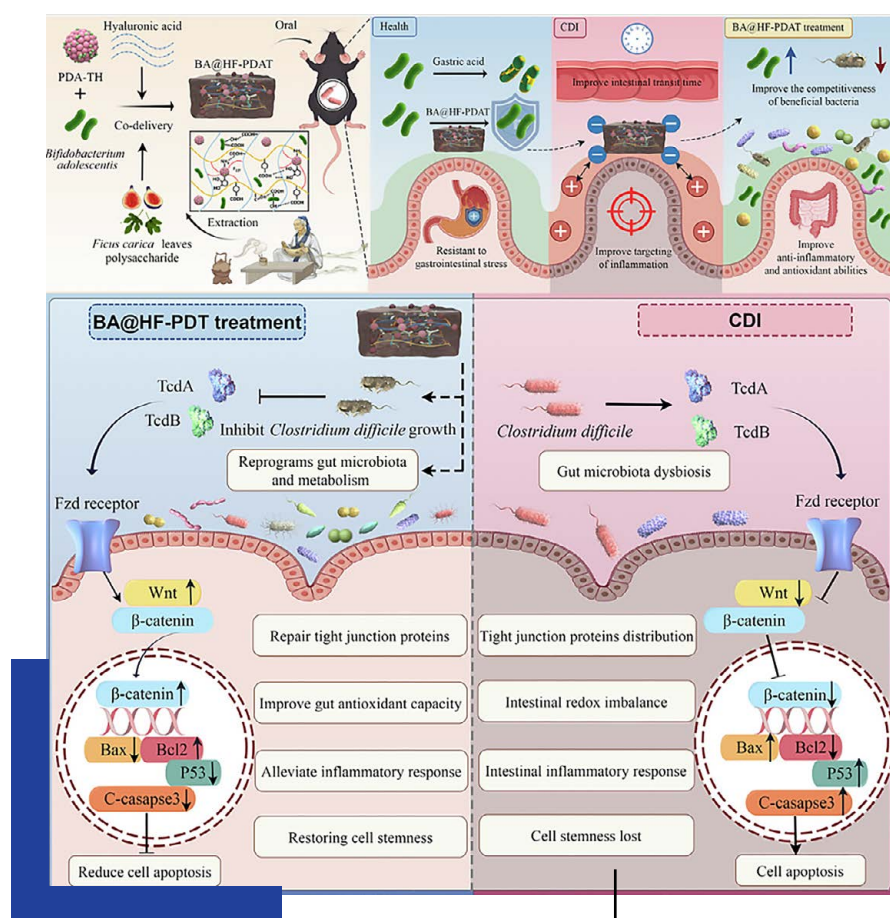
³Harvard University, USA

Clostridioides difficile infection (CDI) is strongly linked to disruptions in gut microbial homeostasis. Although conventional antibiotics effectively inhibit *C. difficile* proliferation, they frequently fail to reestablish microbial equilibrium, thereby constraining therapeutic outcomes. Probiotic therapy seeks to modulate gut microecology by replenishing beneficial microorganisms; however, its clinical efficacy is hindered by poor gastrointestinal survivability, limited colon-targeted engraftment, and inadequate suppression of *C. difficile* virulence determinants.

To address these challenges, a polysaccharide-based hydrogel platform (HF) was developed, named BA@HF-PDAT, designed for the synergistic co-delivery of *Bifidobacterium adolescentis* (BA) and polydopamine-thymol nanoparticles (PDA-TH NPs). HF-mediated encapsulation substantially enhances probiotic viability, facilitates colon- and inflammation-targeted controlled release, and promotes bacterial engraftment.

Concurrently, PDA-TH effectively inhibits *C. difficile* virulence determinants, synergistically amplifying probiotic therapeutic potential. In vitro and in vivo analyses reveal that BA@HF-PDAT facilitates intestinal repair and mitigates apoptosis through Wnt/ β -catenin signaling, exerts potent anti-inflammatory and antioxidant activities, and restores gut microbial composition and metabolic function, thereby effectively ameliorating CDI-induced colitis in murine models. Comparative studies further indicate that BA@HF-PDAT achieves superior therapeutic efficacy compared with vancomycin treatment. Collectively, this integrated co-delivery platform constitutes a promising and translational therapeutic strategy for CDI management.

This research is supported by the NNSFC (32472935), the National Key Research and Development Program (2021YFD1300301).



Graphical abstract of the project.

Identifying a stable carrier for bromoform to deliver enteric methane mitigation

Stephanie Payne¹, Angad Singh¹, Matt Callaghan², Matthew Myers², Nigel Tomkins²
¹School of Agriculture and Environment, University of Western Australia
²ROAM Agricultural Pty Ltd

1 INTRODUCTION

The halogenated compound bromoform has demonstrated consistent methane mitigation for ruminant livestock fed total-mixed rations^{1,2}. However, bromoform is inherently volatile making delivery challenging.

A stabilising carrier is required to facilitate mitigation outcomes on farm and incorporation into supplementary feeds. The objective of this study was to assess the extent of methane mitigation *in vitro* for three inert carriers loaded with bromoform and select the most suitable to progress to *in vivo* studies.



Figure 1. The RUSITEC apparatus.

2 METHODS

- Rumen simulation technique (RUSITEC, Fig. 1) – system stabilisation over 7d then 14 d experimental period.
- Three activated carbon carriers (A, B, C) loaded with 10% bromoform (w/w) and dosed daily *in vitro* at two levels (low, 1.5 µM; L and high, 2.5 µM; H), creating six treatments; AL, AH, BL, BH, CL, CH equivalent to 7.5 and 12.6 mg CHBr₃/kg DM for low and high doses, respectively.
- A substrate only treatment (30 g oats chaff) was used as a control.
- Total gas production measured daily and sub-sampled for methane concentration. Volatile fatty acid and ammonia concentrations, and substrate degradation determined at three timepoints.

3 RESULTS

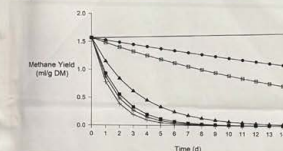


Figure 2. Inhibition of MY (methane yield, ml/g DM incubated) as predicted by an exponential decay model for control (—) and three AC carriers (A, B, C) at a low (L) and high (H) concentration, respectively. AL (▲), AH (●), BL (■), BH (▲), CL (□), CH (◻).

- All six treatments caused significant ($p < 0.0001$) effects on the rate of reduction in methane yield (MY) over 14 d (Fig. 2).
- Rate of daily reduction in MY:
 - 40–50% for treatments BL, BH and CH
 - 27% for treatment AH
 - 2–5% for treatments AL and CL
- A dose dependent response apparent with carriers A and C. Carrier B was equally effective at reducing MY at the low and high dose rates.
- No significant reductions in total VFA. Significantly lower A:P (Table 1) compared with the control.
- Apparent degradation of dry matter (DM), organic matter, neutral detergent fibre and acid detergent fibre decreased over 14 d ($P \leq 0.001$). Significant treatment effect on mean apparent degradation of DM (reductions of $< 7\%$, data not shown).

Table 1. Mean concentration of total volatile fatty acids (VFA), molar proportion of individual VFA, acetate-to-propionate ratio (A:P) and ammonia (NH₃) across treatments *in vitro*.

	Control	AL	AH	BL	BH	CL	CH	SEM	Treatment	Time	Interaction
Total VFA (mmol/L)	94.4	85.1	89.2	83.5	83.6	84.3	84.3	8.28	0.06	<0.001	0.9
Individual VFA (%)											
Acetate	43.1 ^a	40.9 ^a	36.4 ^{ab}	36.2 ^{ab}	35.5 ^a	38.1 ^a	36.3 ^{ab}	0.57	<0.001	<0.001	<0.001
Propionate	15.1 ^a	15.8 ^a	15.9 ^a	16.7 ^a	16.2 ^a	15.1 ^a	17.1 ^a	0.53	0.002	0.02	0.002
Butyrate	26.4	27.8	28.7	28.0	28.5	29.4	27.6	0.55	0.37	<0.001	0.06
A:P	2.9 ^a	2.6 ^a	2.3 ^{ab}	2.2 ^a	2.2 ^a	2.6 ^a	2.2 ^a	0.06	<0.001	<0.001	<0.001
NH ₃ (mg/L)	21.6	20.6	17.3	14.4	17.0	24.9	15.9	2.65	0.059	<0.001	0.9

Superscripts denote significant differences between main effects of treatments ($P < 0.05$) using post hoc comparisons with Tukey's adjustment. P-values for effects of Treatment, Time, and the interaction are shown. A:P acetate to propionate ratio, NH₃ ammonia *in vitro*.



4 CONCLUSIONS & FUTURE WORK

- The MY reduction *in vitro* supports the use of a carrier for bromoform.
- Carrier B was the most effective, achieving significant MY reduction *in vitro* at the low dose.
- Carrier B is the preferred carrier for future *in vivo* trials.

REFERENCES

1. Alenxer, H., et al., 2024. Effects of a range of effective inclusion levels of Apicropagatol on methane production in sheep. *Animal Production Science*, 102, 102052.
2. Li, X., et al., 2020. Apicropagatol decreases enteric methane production from sheep. *Animal Production Science*, 100, 100000.

Evaluation of



Mirka Thorsteinsson
Department of Agriculture

Apicropagatol is a feed additive that reduces methane production in sheep. However, freeze-drying is energy intensive. Recent studies have shown that the preservation method of bromoform

Material

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The RUSITEC apparatus.

Dr Stephanie Payne presenting this research at the 9th International Greenhouse Gas & Animal Agriculture Conference in Nairobi, Kenya, October 2025.

Identifying a stable carrier for bromoform to deliver enteric methane mitigation

Project team: Dr Stephanie Payne¹ (project leader; stephanie.payne@uwa.edu.au), Dr Zoey Durmic¹, Dr Suyog Subedi¹, Dr Joy Vadhanabhuti¹, Angad Singh¹, Matt Callaghan², Dr Nigel Tomkins², Dr Matt Myers², Imran Mozumder²

Collaborating organisations: ¹UWA; ²ROAM Agricultural

The halogenated compound bromoform has demonstrated consistent methane mitigation for ruminant livestock fed total-mixed rations. However, bromoform is an inherently volatile compound, making delivery challenging. A stabilising carrier is required to facilitate mitigation outcomes on farm and incorporation into supplementary feeds.

The UWA Rumen Methane Group has been collaborating with ROAM Agricultural since 2023, assessing bromoform formulations for their effects on rumen fermentation as ROAM Ag progressed through their product development phase. Most of the work involved testing the ROAM Agricultural formulations in the Rumen Simulation Technique (RUSITEC) experiment, an 'artificial rumen' continuous fermentation system run with ruminal fluid collected from donor sheep (UWA animal ethics approval 2021/ET001086). The RUSITEC allows in-depth assessment of the effect of treatments on microbial fermentation and methane over 2 weeks, an invaluable experimental step before testing in animals.

In 2025 the final stage of the collaboration assessed bromoform stabilised with three different activated carbon carriers in the RUSITEC. One carrier stood out as the most effective, achieving significant daily reductions in methane over two weeks resulting in complete inhibition without negatively affecting overall fermentation. This carrier demonstrated good thermal stability, and the loading capacity suggests it would be more cost-effective than the current oil-based carriers used for bromoform additives. The carrier was selected to progress to cattle trials with ROAM Ag.

This research is supported by ROAM Agricultural.



MERiL team from left to right: Research assistant Janet Kok, Research Fellow Dr Stephanie Payne, and research assistants Sam Lloyd and Angad Singh.

MERiL stage 3 part 1: A national approach to methane mitigation

Project team: Dr Zoey Durmic¹ (project leader; zoey.durmic@uwa.edu.au), Dr Stephanie Payne¹, Dr Suyog Subed¹, Dr Joy Vadhanabhuti¹, Professor Julius van der Werf³, Dr Daniel Sitienei³, Dr Alice Weaver², Dr Alyce Lowe²

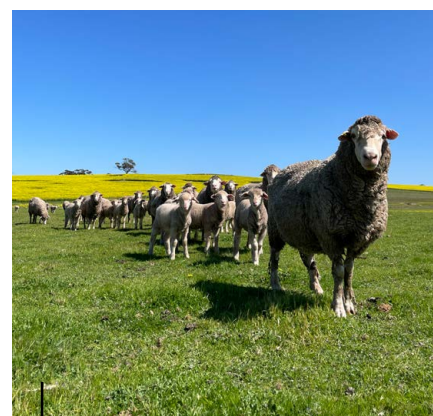
Collaborating organisations: ¹UWA; ²PIRSA-SARDI; ³UNE

This project was a collaborative effort of the National Sheep Methane Program (NSMP) participating organisations UWA, the Department of Primary Industries and Regions South Australian Research and Development Institute (PIRSA-SARDI) and The University of New England (UNE), with the support of the Department of Industry, Science, Energy and Resources (DISER) and industry partners Australian Wool Innovation (AWI) and Feedworks.

Enteric methane emissions from livestock systems are the primary source of agricultural greenhouse gas emissions. Recently, several feed additives have shown promising results in mitigating enteric methane in animals fed in confinement. However, up to 95 per cent of ruminant production in Australia occurs under grazing systems. Therefore, this project aimed to quantify the level of methane mitigation achievable with these products in sheep under grazing conditions over an extended period. Furthermore, it investigated the effects of these feed additives on animal productivity and health.

At the UWA site, the essential oil-based additive Agolin Ruminant® (Agolin) was investigated. The trial was conducted over a 16-month period at UWA Farm Ridgefield with 225 mature Merino ewes. Supplementary pellets were delivered via lickfeeders during summer and autumn months and included Agolin at a low or high dose, alongside a control pellet. Methane emissions were estimated using GreenFeed units (C-Lock, USA), in-paddock measurement systems that allow estimation of daily methane emissions from individual sheep based on averaging multiple short-term measurements taken while the animal is eating food from the unit. Additionally, the effects of Agolin supplementation on reproduction was assessed by comparing lambing performance. Meat and wool quality were also compared, and health was monitored through analysis of rumen fermentation and blood parameters.

Average reductions in methane production of approximately 18 per cent and 25 per cent were observed (but not significant) with supplementation of the Low Agolin and High Agolin pellets, respectively. Methane reduction was season dependent in this study with reductions seen across summer but not autumn and early winter. The inconsistency in the methane results are thought to be mainly due to differences in the feedbase and feed intake over time, however challenges in the implementation



Some of the MERiL3-ewes and lambs.

of the GreenFeed units also affected data. Agolin had no measurable impact on wool production, meat quality, or reproductive performance. Our findings suggest that Agolin may offer mild antimethanogenic activity in grazing sheep when delivered via supplementary pellets, however, may be constrained by variability in feedbase and intake. This study has also highlighted the practical challenges of measuring emissions under extensive conditions, and these learnings have contributed to the development of the next stage of MERiL3 work at UWA.

This study was the first to assess Agolin in grazing conditions in a long-term trial and has generated substantial data which can be used to inform future methane mitigation strategies for Australian grazing systems.

This research is supported by the DISER, AWI and Feedworks.

MERiL stage 3 part 2: Validating and delivering market-ready feed additive solutions in sheep

Project team: Dr Zoey Durmic¹ (project leader; zoey.durmic@uwa.edu.au), Dr Stephanie Payne¹, Dr Suyog Subed¹, Dr Joy Vadhanabhuti¹, Jay Prakash Ray¹, Professor Julius van der Werf³, Dr Daniel Sitienei³, Dr Alice Weaver², Dr Alyce Lowe², Dr Jamee Daly², Dr Jessica Wallace⁴

Collaborating organisations: ¹UWA; ²PIRSA-SARDI; ³UNE; ⁴NSW-DPIRD

This project is a collaborative effort of the NSMP participating organisations UWA, PIRSA-SARDI, UNE and NSW-DPIRD with the support of the DISER and industry partners AWI, Feedworks and ProAgni.

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 co-benefits to productivity.

The UWA node of the project is investigating the antimethanogenic essential oil compound linalool. Previous UWA work has shown that linalool has a strong methane reducing effect, but no known benefits to rumen function/productivity. Conversely, the feed additives Agolin Ruminant and ProTect-S are two multi-ingredient feed additives which can improve rumen function and productivity, with moderate antimethanogenic effect. Thus, the aim of the UWA team is to compare which feed additive combination with linalool can provide greatest benefits to grazing sheep production systems.

Project work at UWA commenced in 2025 with a rumen simulation experiment (RUSITEC) to select optimal combinations and refine the doses to be tested on farm. Master of Agricultural and Environmental Biotechnology student Jay Prakash Ray successfully carried out this portion of the project for his research dissertation.

In February 2026, a 12-month grazing trial at UWA Farm Ridgefield began, with the additive combinations delivered in pellets to growing sheep. The trial will measure methane emissions via GreenFeed units, liveweight gain, wool quality, rumen fermentation and blood parameters. At the end of the project the NSMP will have clear outcomes for grazing sheep systems in terms of the efficacy, productivity benefits, and practicality of delivering feed additives that are relatively close to market.

This research is supported by DISER, AWI, Feedworks and ProAgni.



The RUSITEC testing additive combinations.



A GreenFeed unit set up at Ridgefield.



Sensor-equipped sheep at the UWA Farm Ridgefield.

Investigating heat stress in ewes – Reproductive performance

Project team Professor Shane Maloney¹ (project leader; shane.maloney@uwa.edu.au), Dr Kelsey Pool¹, Professor Dominique Blache¹, Dr David Walker¹, Associate Professor Amin Muger¹, Associate Professor Serina Hancock², Georgia Welsh², Dr Hayley Norman³

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

Extreme heat events increasingly threaten sheep productivity and welfare in Australia's extensive grazing systems. While the impacts of heat stress on reproduction are well documented, almost all research has been conducted under controlled conditions, leaving a critical gap in understanding real-world paddock responses. This project addresses the gap by investigating how sheep use microclimatic resources, such as shade, vegetation, and topography, to mitigate heat stress during mating. Using advanced sensor technologies and environmental monitoring, the study identified key behavioural and physiological strategies that enhance thermal resilience. These insights inform practical management tools and breeding programs to improve welfare and reproductive performance under warming climates.

The project addressed three objectives:

- 1) Quantify the effects of heat events on sheep reproduction, thermoregulation, behaviour, and wellbeing through long-term data collection across diverse climatic conditions and production systems.
- 2) Collect and integrate physiological, behavioural, and environmental data to a comprehensive understanding of heat stress impacts under real-world conditions.

- 3) Identify mitigation strategies to reduce reproductive losses associated with heat stress in sheep production systems.

The project was conducted over three years on a research farm and on four commercial properties to capture real-world grazing conditions and microclimate variability, including variation in paddock characteristics, weather data, and the level of shade that was available to the sheep. Three of the commercial sites were in the wheatbelt and one was in the Southern rangelands of WA.

At the experimental site, the ewes were joined in paddocks that had different levels of shade over three years, and on the commercial farms there was some variability in the shade and reproduction was measured over two to three years. On the commercial farms, the sheep were exposed to the natural landscape of the paddock. Physiological and behavioural data were collected using sensor technologies and environmental monitoring.

Merino sheep reproduction is strongly influenced by radiant heat load, interacting with timing of shearing relative to joining, shade availability, and adaptive behaviours that mitigate heat stress. Heat load also has lasting negative effects on ram sperm, which can be alleviated using long-acting melatonin. The project delivered robust GPS, rumen temperature, and accelerometer technologies, alongside advanced data pipelines and significant postgraduate and international researcher training.

The project shows that THI alone does not predict the impact of heat stress in sheep, highlighting the need for a thermal



Close-up of the equipment on a sheep collar.

index that incorporates solar radiation. It demonstrates that shearing timing, shade access, and ram management influence reproduction. Novel, affordable monitoring technologies enable industry-wide assessment of heat-stress, animal selection, and application across sheep, cattle, and broader red-meat systems.

Further research is needed to clarify the impact of heat-load on sheep reproduction, adaptation, and resilience. Proposed studies include multi-year time of shearing trials, radiation and physiology experiments, ram heat-history effects, genetic and epigenetic adaptation, improved heat indices, breed comparisons, shrub-based mitigation strategies, and microbiome links to reproduction and sustainability. The main recommendation is that the timing of shearing, shade, water access, and ram management are critical to reduce heat load, protect sperm integrity, and sustain reproduction.

This research is supported by MLA and UWA.

The change in rumen temperature post-drink can be used to estimate water intake in sheep

Project team: Georgia Welsh² (project leader; georgia.welsh@murdoch.edu.au), Dr Serina Hancock², Dr Luoyang Ding¹, Professor Dominique Blache¹, Professor Shane K. Maloney¹

Collaborating organisations: ¹UWA; ²Murdoch University

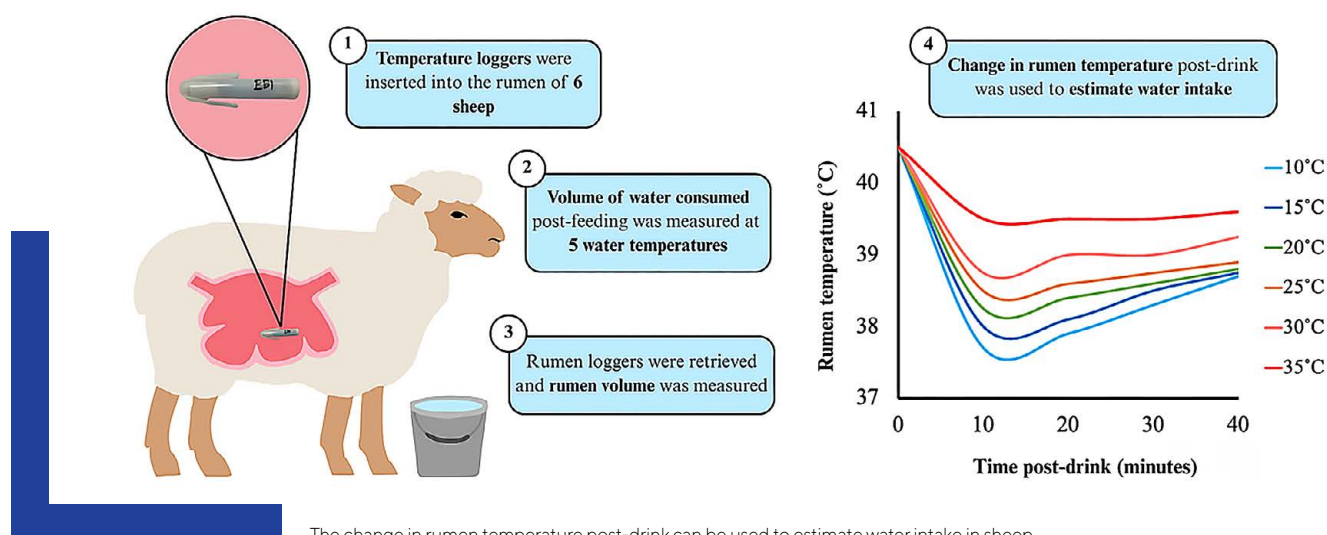
In ruminants, water ingestion causes an immediate and measurable decline in rumen temperature. While this physiological response is well established, its application for estimating water intake has not previously been investigated. This study assessed the suitability of a thermodynamic modelling approach to estimate water intake in sheep using intra-ruminal temperature data. A fluid calorimetry equation was first validated under controlled laboratory conditions, then applied to data from six sheep

fitted with intra-ruminal temperature loggers. Animals were offered water of known volume and temperature, and intake estimations were calculated using the temperature drop, baseline rumen temperature, water temperature, and estimated rumen volume based on liveweight. To improve volume estimation, additional rumen volume and liveweight data from a separate group were used to generate a generalised prediction equation for rumen volume.

The approach underestimated the volume of water consumed, and so a correction factor was developed to account for physiological variation in the effective rumen volume at the time of drinking. Using the effective rumen volume in calculations resulted in estimated intake volumes that generally aligned with the measured values ($P < 0.01$).

The results demonstrate that measured changes in intra-ruminal temperature can be used to estimate water intake, offering a promising tool for precision livestock monitoring in extensive grazing systems

This research is supported by MLA (P.PSH.1292) and WALRC.



The change in rumen temperature post-drink can be used to estimate water intake in sheep.



Honey bee collecting pollen.

Environmental cues rather than quality of supplemented pollen drive the foraging behaviour of honey bees during avocado pollination

Project team: Dr Madlen Kratz^{1,2} (project leader; madlen.kratz@dpi.nsw.gov.au), Dr Robert Manning^{3,4}, Dr Lynne Milne⁵, Kenneth Dods^{6,7}, Professor Boris Baer⁸, Professor Dominique Blache¹

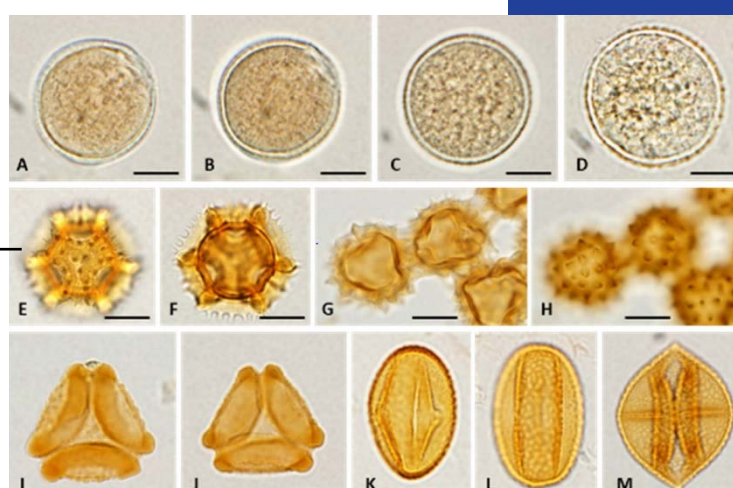
Collaborating organisations: ¹UWA; ²New South Wales Department of Primary Industries; ³Western Australian Department of Agriculture and Food; ⁴RMO Consultancy; ⁵Curtin University; ⁶ChemCentre; ⁷Sage Consultancy; ⁸University of California Riverside, United States of America

Honey bee colonies adapt their foraging behaviours to the availability of floral resources to meet their nutritional needs. However, it is unknown if the nutritional quality of stored or supplemented pollen can influence the floral choices of bees during commercial crop pollination. The foraging behaviour of bees from 40 colonies was studied during avocado pollination in southern Western Australia.

A pollen database of the orchard was built and used to assess the floral preference of the bees. Pollen collectors and nectar foragers showed different foraging behaviour as indicated by their Dominance Candidate Index (DCI). The foraging choices were partially affected by the type of supplemented pollen that consisted of agricultural and forest species. Aside from nutritional cues, floral source abundance and attractiveness played a role in influencing the foraging behaviour for pollen and nectar. Both pollen and nectar foragers chose a subset of flowers available at the avocado orchard. Foraging bees respond strongly to various environmental cues that potentially underlie energetic investment and food reward principals.

This research is supported by the Australian Government RTP Scholarship, ARC grants (LP100100438, DP130100087, LP130100029, FT110100105), DPIRD Grower Group Research and Development Grants Program (GGRD 2015-0028-AGSC), CIBER - Future Bees Fund and BICWA.

Photomicrographs of prominent pollen types (>5 per cent) of reference flowers identified to the species level. (A–D) *Persea americana* (avocado) not acetolysed. (A, B) same grain, high and median focus, (C) median focus, (D) larger hydrated grain. (E, F) *Hypochaeris radicata*, high and median focus respectively. (G, H) *Arctotheca calendula*, median and high focus respectively. (I, J) *Eucalyptus marginata* (jarrah) showing range of morphology. (K–M) *Trifolium repens* (clover). (K, L) median and high focus of equatorial view, (M) high focus of polar view. Scale bars 10 μ m (=magnification x1000).





Dr Kelsey Pool and PhD student Whitney Payne during one of their visits to Wyloo station for producer consultation.

Hot and hormonal: Investigating antioxidant strategies to improve reproduction and thermal resilience of livestock

Project team: Dr Kelsey Pool^{1,2} (project leader; kelsey.pool@uwa.edu.au), Whitney Payne¹, Professor Shane K. Maloney¹, Dr Serina Hancock², Shannon Thompson, Clint Thompson

Collaborating organisations: ¹UWA; ²Murdoch University; ³DPIRD; ⁴Gascoyne Pilbara Rangelands Initiative (GPRI)

Projected increases in temperature and frequency of heatwaves as a result of climate change will challenge the sustainability of cattle raised in extensive pastoral systems of Australian rangelands.

Heat stress can impair the reproductive performance of livestock by disrupting endocrine function and causing seasonal or chronic subfertility or infertility in both males and females. Mechanistically, these disruptions are partly attributed to rises in oxidative stress induced by elevated temperature exposure. Reducing oxidative stress during periods of heat stress through the supplementation of dietary antioxidants may improve the fertility and thermal resilience of livestock, providing producers with a viable mitigation strategy for livestock management in a changing climate. This project will explore the potential of vitamin E supplementation as a strategy for cattle pastoralists to improve the thermal resilience and reproductive performance of their herds.



Cattle grazing in an extensive rangeland paddock at Wyloo station, in the Pilbara region of WA.

This project also aims to address knowledge gaps surrounding the underlying mechanisms driving interactions between heat stress and reproduction in extensive pastoral systems. The study will be conducted at a cattle station in the Pilbara region of Western Australia, proudly co-designed with the station managers, and will run for two and a half years. The study will use intra-ruminal biosensors, GPS tracking collars, weather stations, and involve the collection of biological and vegetation samples to provide extensive data on cattle behaviour and physiology.

The findings of the study will provide novel insights into the effects of thermal stress on cattle reproduction in the region and provide a comprehensive baseline dataset that will support producers and future research in northern Western Australian rangelands.

This research is supported by MLA, WAARC, The Northern Drought Hub, PIP, UWA and South-West WA Drought Hub.

The intricate relationship between stress and animal welfare: From historical perspective to new avenues

Project team: Professor Dominique Blache^{1,2} (project leader; dominique.blache@uwa.edu.au), Feifan Wu^{1,2}, Professor Alan Tilbrook³, Professor Shane Maloney¹

Collaborating organisations:¹UWA, ²Yangzhou University, China, ³University of Queensland

This study discusses the intricate relationship between the evolution of the concept of stress and the development of the concept of animal welfare. After a brief review of the main concepts of animal welfare, important steps in the evolution

of the concept of stress are analysed, starting from the mechanistic approach of the General Adaptation Syndrome to the recent integrative allostatic theory. This study shows how, over time, each concept of stress has informed the development of the concept of animal welfare. The role of emotions and affective states in the response of animals to challenges is discussed, along with the way psychological stress is considered integral to animal welfare. Lastly, the potential role of the gut-brain axis in both the concept of stress and welfare is briefly discussed.

This research is supported by the Postgraduate Research & Practice Innovation Program of Jiangsu Province (Project No.: KYCX24_3808) and the International Academic Exchange Fund for Graduate Students of Yangzhou University, China.

Sheep in the field at UWA Farm Ridgefield.





Montana Walsh Baddeley presenting her research proposal for feedback.



In the yards learning more about cattle station operations.

In search of the Super Cow: The genetic and behavioural factors influencing body composition in WA rangelands beef cattle

Project team:

Professor Dominique Blache¹ (project leader; dominique.blache@uwa.edu.au), Montana Walsh Baddeley¹ (project leader; Montana.walshbaddeley@research.uwa.edu.au), Dr Matt Wolcott², Dr Fiona Dempster¹

Collaborating organisations:

¹UWA; ²AGBU, UNE, PIP

Western Australian rangelands beef production is subjected to highly variable climatic conditions, making adaptability and efficiency vital to maintaining productivity. To produce a calf every year in a resource-restrictive environment, breeding cows must effectively manage resources between lactation, recommencement of reproduction and their own maintenance/growth. Reproductive efficiency is closely linked with body composition, however, the underlying genetics for body composition are poorly understood relative to other performance traits. Body composition is likely also influenced by individual grazing behaviours, which are heritable but understudied in Australian rangeland environments. Improved understanding of individual-level factors influencing body composition could enable the development of tools to assist producers with selection and management to improve cattle efficiency. Given historically lower rates of breeding tool adoption in the rangelands, understanding barriers to adoption could inform extension practices to support producers with their breeding goals.

To investigate these knowledge gaps, the researchers will take a phenotype-focused approach to improving reproductive efficiency in the WA rangelands. They intend to 1) identify individual-level traits affecting female reproduction through literature review and producer survey; 2) investigate the genetics and genomics of cow body composition, to contribute toward the development of a new BREEDPLAN Estimated Breeding Value; 3) quantify rangeland cattle grazing behaviours, effects on performance, and interactions with genetics through experiments using GPS data and bio-loggers; 4) understand barriers to adoption of breeding tools through producer interviews. By employing an interdisciplinary approach to genetic research, this PhD project aims to improve the adoption, effectiveness and specificity of genetics improvement strategies in the WA rangelands, ultimately benefiting both producers and the wider cattle industry.

Montana received a WAARC top-up scholarship to support her research, and although she did not commence until mid-May 2025, she has been involved with several WAARC cohort events including workshops on presentation and writing skills, as well as featuring on the WAARC podcast.

Montana attended the PIP Pilbara Showcase at Hillside Station, the KPCA Conference in Broome, and the WALRC Livestock Matters forum in Gingin, building

connections with several rangelands producers and industry partners. She also visited a cattle station in the East Pilbara, seeing the cattle work first-hand and discussing how the next stages of their PIP Pilbara Extension Network project could work in with Montana's PhD goals.

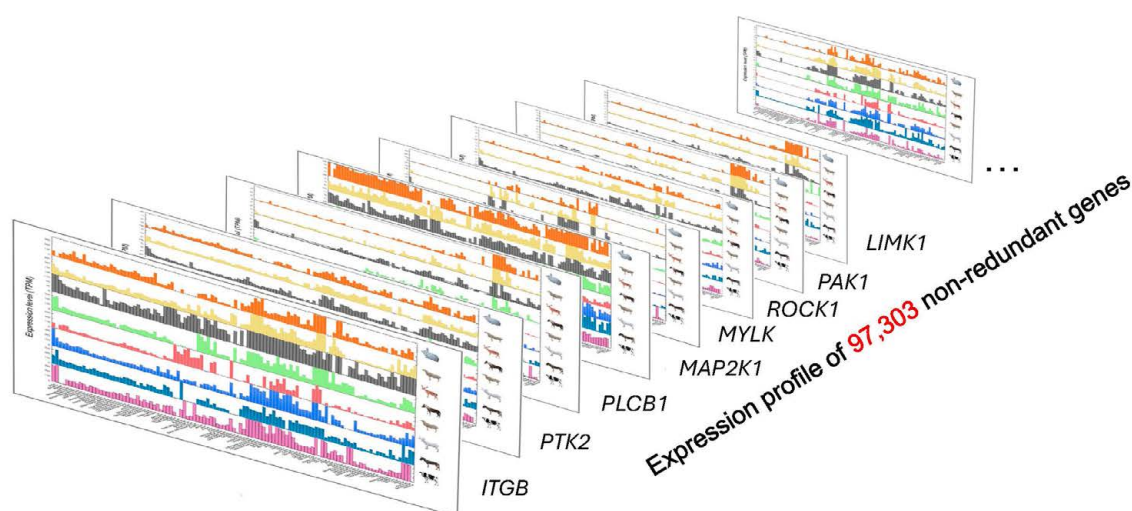
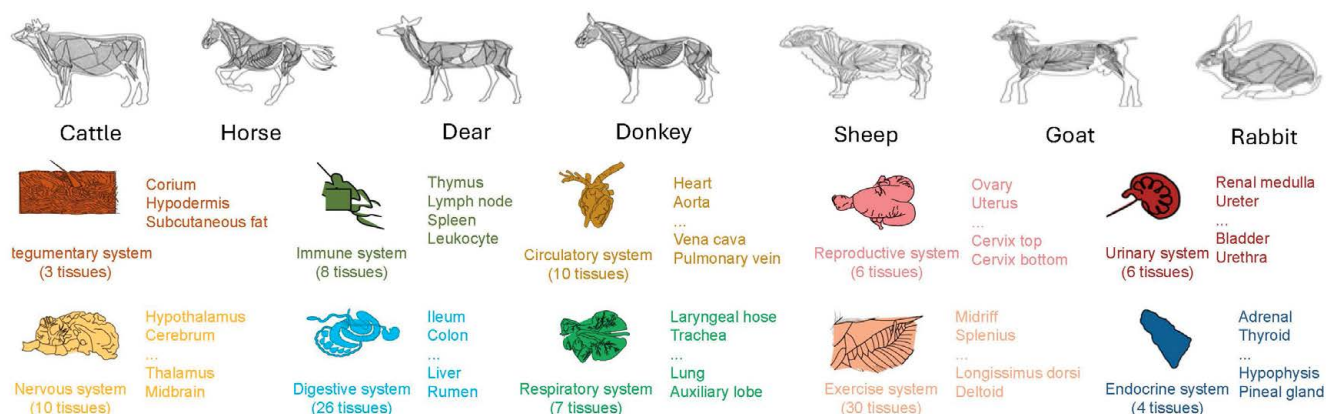
Montana spent two months hosted by co-supervisor Dr Matt Wolcott at the Animal Genetics and Breeding Unit in Armidale NSW, broadening her understanding of quantitative genetics techniques and commencing work on her first experimental chapter. Her preliminary results are looking very promising for the industry and have enabled her to put newly learnt genetics skillsets into practice.

Montana's research proposal was approved in October 2025, and she is now working on her literature review and first experimental chapter toward her Confirmation of Candidature in May 2026.

Montana thanked her supervisors, Professor Dominique Blache, Dr Matt Wolcott, and Dr Fiona Dempster, for all their support and guidance so far. She also thanked WAARC, AGBU, PIP, UNE, and UWA for their support and collaboration.

This research is supported by WAARC, HDR Top-Up Scholarship and UWA RTP Stipend - Domestic Student.

105 different tissues from each of 7 species of domestic herbivore



An overview of the HTIRDB database.

The *HTIRDB*: A resource containing a transcriptional atlas for 105 different tissues from each of seven species of domestic herbivore

Project team: Dr Luoyang Ding^{1,2} (project leader; luoyang.ding@uwa.edu.au), Yifan Wang², Dr Linna Zhang³, Chengfang Luo³, Feifan Wu^{1,2}, Yiming Huang³, Dr Yongkang Zhen², Dr Ning Chen⁴, Dr Limin Wang⁴, Professor Li Song⁵, Dr Kelsey Pool¹, Professor Dominique Blache¹, Professor Shane Maloney¹, Dr Dongxu Liu³, Dr Zhiqian Yang³, Dr Xiaoyan Huang³, Chuang Li², Xiang Yu², Dr Zhenbin Zhang², Yifei Chen², Chun Xue², Yalan Gu², Weidong Huang², Lu Yan², Wenjun Wei², Yusu Wang², Dr Jinying Zhang², Yiquan Sun², Dr Rui Dai³, Dr Shengbo Wang³, Dr Xinle Zhao³, Dr Haodong Wang³, Professor Ping Zhou⁴, Professor Qing-Yong Yang^{3,4}, Professor Mengzhi Wang⁴

Collaborating organisations: ¹UWA; ²Yangzhou University, China; ³Huazhong Agriculture University, China; ⁴Xinjiang Academy of Agricultural Reclamation, China; ⁵Guizhou University, China

Domesticated herbivores are essential to global food security due to their adaptability to diverse and marginal environments. Understanding their molecular biology can improve sustainable management and productivity. Comparative transcriptomics is a powerful approach for studying gene–environment interactions and biological adaptation.

Although several transcriptomic atlases and databases exist for livestock species such as cattle, pigs, sheep, goats, and others, they face notable limitations. For example, the existing datasets are highly heterogeneous, as RNA-seq libraries are often compiled from multiple independent studies without standardized protocols for sampling, sequencing, or data processing. Secondly, data completeness is inconsistent, with many databases covering only a limited number of tissues. Third, current resources lack sufficient depth for cross-species and cross-tissue comparative analyses, restricting insights into gene function, tissue differentiation, and evolutionary patterns.



Group photo of researchers on sample collection day at UWA Shenton Park Field Station.

To address these challenges, the authors developed HTIRDB, a comprehensive and standardized herbivore transcriptome database. It integrates 1,642 newly generated RNA-seq libraries from 100–105 tissues per species across seven herbivores (including sheep, cattle, goat, horse, donkey, deer, and rabbit), alongside 34,326 publicly available RNA-seq datasets. All newly generated samples were collected under strict, uniform protocols to ensure high quality and comparability, with rapid tissue preservation and rigorous data processing pipelines yielding high sequencing and alignment quality.

HTIRDB provides extensive tissue coverage across ten organ systems, enabling holistic analysis of gene expression. A hierarchical coding system standardises tissue identification across species, improving data organization and retrieval. The platform also offers diverse analytical tools suitable for both non-specialists and bioinformaticians. These include gene expression visualization through electronic Fluorescent Pictographs (eFP), comparative transcriptomics, co-expression networks, and functional enrichment analyses (GO and KEGG), as well as sequence alignment and retrieval tools.

Overall, HTIRDB represents the most comprehensive herbivore transcriptome atlas to date. It facilitates cross-species and cross-tissue analyses, supports the discovery of genes linked to important biological and economic traits, and advances research in evolution, functional genomics, and livestock improvement.

This research is supported by the State Key Laboratory of Sheep Genetic Improvement and Healthy Production and the National 14th 5Year Plan Key Research and Development Program of China.



Lake in Margaret River, Western Australia.

3

Water for Food Production

Theme Leader

Professor Sally Thompson
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The Water for Food Production theme focuses on improved efficiencies in irrigated agriculture and better use of finite water resources to meet the food needs of an increasing world population. Thirty-seven per cent of the world's total land area is available for agricultural production, approximately 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 through water conservation, requiring an understanding of how direct evaporative losses and deep drainage losses below the rootzone can be minimised.

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

Wild Cicer species exhibit superior leaf photosynthetic phosphorus and water-use efficiencies compared with cultivated chickpea under low-phosphorus conditions

Project team: Dr Jiayin Pang¹ (project leader; jiayin.pang@uwa.edu.au), Hackett Professor Kadambot Siddique¹, Emeritus Professor Hans Lambers¹, Professor Rajeev K. Varshney², Simiao Li¹, Professor Ulrike Mathesius³, Associate Professor Jens Berger^{1,4}, Dr Weina Zhang⁵; Dr Komal D Sawant⁶

Collaborating organisations: ¹UWA; ²Murdoch University; ³Australian National University; ⁴SCIRO; ⁵Hanghuai University, China; ⁶Nowrosjee Wadia College, India

Chickpea (*Cicer arietinum*) is an important food and feeding legume, but domestication has greatly reduced its genetic diversity. This study evaluated the effects of chickpea domestication on phosphorus (P)-use efficiency (PUE) under low-P conditions using a diverse *Cicer* collection, including wild species. The experimental material included 54 accessions of *C. reticulatum*, 15 accessions of *C. echinospermum*, and seven accessions of domesticated *C. arietinum*, all grown in low-P soil.

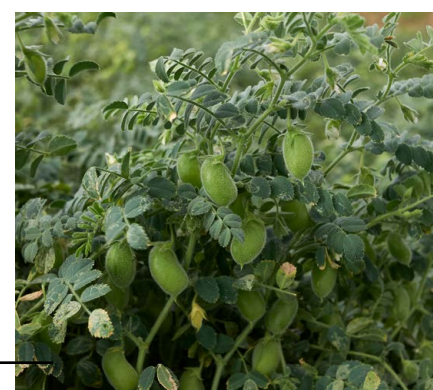
Significant variation was observed among species and among accessions within each species for shoot and root dry weight, root mass ratio, shoot and root P contents, physiological PUE, leaf gas exchange characteristics, photosynthetic PUE (PPUE), and photosynthetic N-use efficiency (PNUE). Variation was greater in wild *Cicer* species than in domesticated *C. arietinum*.

Domestication increased shoot growth and total leaf area but reduced root mass ratio. Compared with domesticated *C. arietinum*, wild *Cicer* species exhibited lower stomatal conductance and higher leaf mass per area, resulting in lower intercellular CO concentration and higher water-use efficiency (WUE). Elevated leaf nitrogen concentrations in wild *Cicer* species were associated with enhanced photosynthetic capacity, partially compensating for reduced stomatal conductance.

Wild *Cicer* species demonstrated higher PPUE but lower PNUE than domesticated chickpea, indicating a trade-off between increased WUE and PNUE. These findings highlight the potential of wild *Cicer* species to enhance PPUE in breeding programs, which may reduce dependence on P fertilisers. Further investigation of the mechanisms underlying higher PPUE in wild *Cicer* is warranted. Further investigation of the mechanisms underlying higher PPUE in wild *Cicer* is warranted.

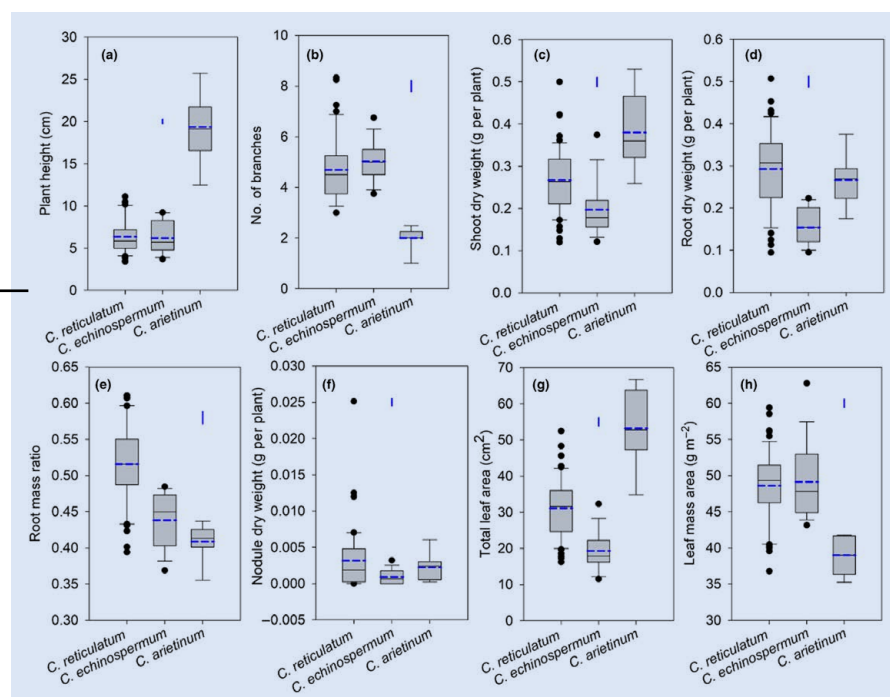
These findings highlight the potential of wild *Cicer* species as valuable genetic resources for providing donor genes to improve PPUE in chickpea breeding programs. Extrapolation of these results beyond the vegetative stage requires additional experimentation. To strengthen accession selection, identified accessions should be validated for desirable traits under varying soil types and environmental conditions across multiple field sites.

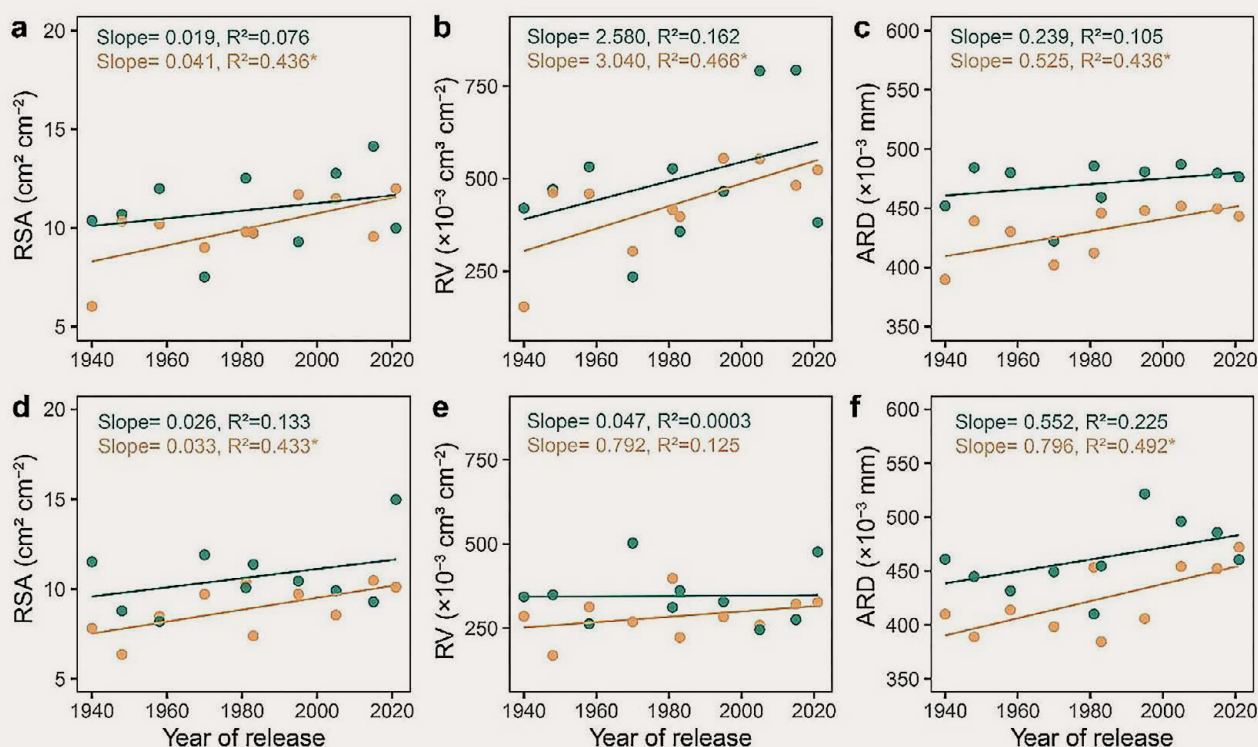
This research is supported by ARC (LP200100341).



Cicer arietinum in the field.

Box plots showing (a) plant height, (b) branch number, (c) shoot dry weight, (d) root dry weight, (e) root mass ratio, (f) nodule dry weight, (g) total leaf area, and (h) leaf mass area in three *Cicer* species – 54 *C. reticulatum*, 15 *C. echinospermum*, and seven *C. arietinum* accessions – grown under low-P conditions for 9 wk in a temperature-controlled glasshouse. Solid and dashed central bars in each box represent the median and mean, respectively. The box represents the interquartile range, the whiskers indicate the location of the most extreme data that are still within a factor of 1.5 of the upper or lower quartiles, and the black points are values that fall outside the whiskers. The blue vertical bars represent LSD0.05 between species.





Relationships between cultivar release year and (a, d) root surface area (RSA), (b, e) root volume (RV), and (c, f) average root diameter (ARD) in the 0–100 cm soil profile under reduced (green) and normal (orange) fertilization during the (a–c) 2022–2023 and (d–f) 2023–2024 wheat growing seasons in Yangling, Shaanxi, China. Significance levels: * $P < 0.05$, ** $P < 0.01$, and *** $P < 0.001$

Breeding and nitrogen management shape root morphology and water use efficiency in wheat in the Huang-Huai-Hai region of China.

Breeding and nitrogen management shape root morphology and water use efficiency in wheat in the Huang-Huai-Hai region of China

Project team: Dr Xiaoliang Qin² (project leader; xiaoliangqin2006@163.com), Dr Tiantian Huang³, Dr Zhuanzhuan Zhang², Dr Xiaoli Zhong², Dr Ruiqi Sun², Dr Xiaoru Zhao², Dr Qianxiang Wu², Dr Shiguang Wang², Dr Xiaohua Yang², Hackett Professor Kadambot Siddique¹

Collaborating organisations: ¹UWA; ²Northwest A&F University, China; ³Henan Agricultural University, China

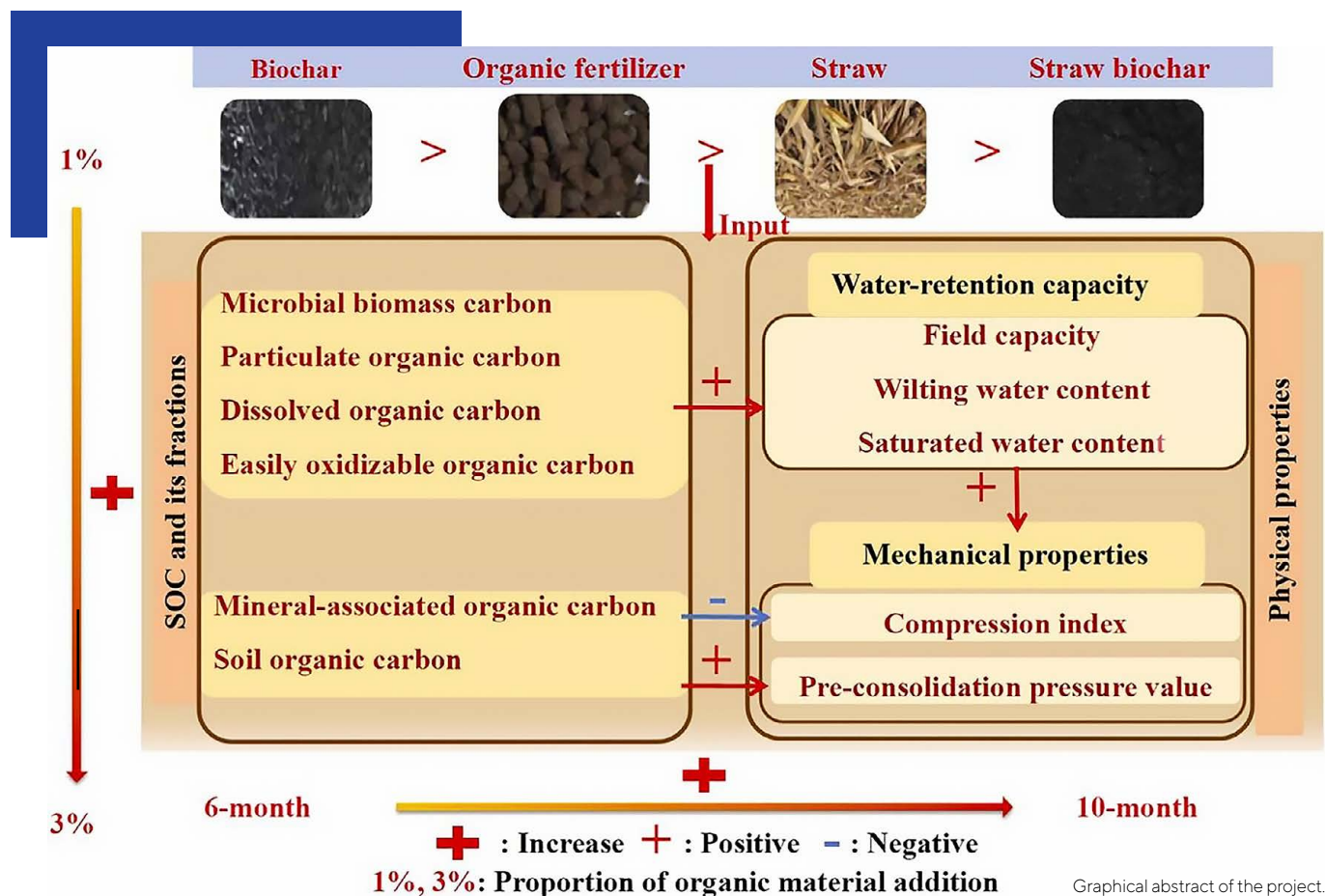
The root system of wheat is crucial for soil moisture uptake, grain yield, and grain water use efficiency (WUEg). Genetic improvements and nitrogen (N) fertilisation influence root morphology. Understanding how root systems have changed across wheat varieties under varying N conditions is critical for future breeding and nutrient management.

A two-year field experiment examined ten key winter wheat varieties released between 1940 and 2021 in the Huang-Huai-Hai region, China. Root architecture, distribution, evapotranspiration, grain yield, WUEg, and the water use efficiency of aboveground biomass (WUEp) were evaluated under normal (220 kg N ha⁻¹) and reduced (143 kg N ha⁻¹) N applications.

WUEg improved progressively with variety release year under both N regimes, though the underlying mechanisms differed. Under reduced N, modern cultivars developed greater root length density in subsurface (20–40 cm) and deep (40–100 cm) soil layers, enhancing deep moisture uptake. Under normal N, root growth was concentrated in the topsoil (0–20 cm), enabling modern varieties to use soil moisture more effectively. Genetic selection has reduced pre-anthesis water use while increasing post-anthesis use, particularly in dry years.

The past eight decades of winter wheat breeding have increased grain yields and improved WUEg through deeper rooting, particularly under low N conditions.

This research is supported by the NNSFC (No. 32272217).



Graphical abstract of the project.

Effect of organic amendments on soil organic carbon fractions, water retention, and mechanical properties in a Chinese Alfisol

Project team: Dr Xiaoliang Qin³ (project leader; xiaoliangqin2006@163.com), Dr Danyang Wang², Dr Tingting Tan^{2,3,4}, Dr Jing An^{2,3,4}, Dr Xinxin Jin^{2,3,4}, Dr Hongtao Zou^{2,3,4}, Dr Yuling Zhang^{2,3,4}, Dr Na Yu^{2,3,4}, Hackett Professor Kadambot Siddique¹

Collaborating organisations: ¹UWA; ²Shenyang Agricultural University, China; ³Ministry of Agriculture and Rural Affairs, China; ⁴National Engineering Research Center for Efficient Utilization of Soil and Fertilizer Resources, China

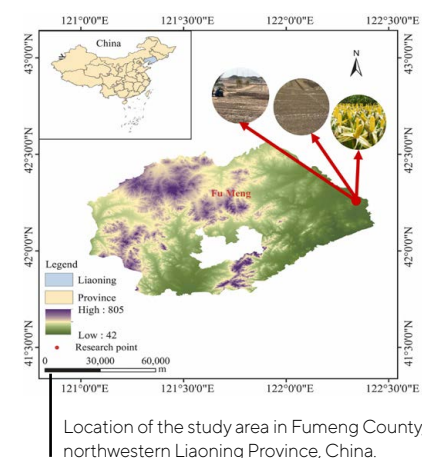
This study examined how different organic amendments affect soil organic carbon (SOC), water retention, and soil mechanical behaviour in degraded Alfisols from Northeast China. A 10-month incubation experiment tested straw (ST), biochar (BR), organic fertiliser (OR), and straw biochar (SBR) applied at 1 per cent and 3 per cent rates to assess changes in SOC fractions, moisture dynamics, and compaction resistance.

Results showed that both amendment type and application rate strongly influenced soil properties. SOC and its fractions

increased over time across all treatments, with the greatest improvements observed under biochar application, particularly at the 3 per cent rate. This treatment was most effective in raising mineral-associated organic carbon (MAOC), which contributed to improved soil structural stability.

Improvements in SOC were closely linked to enhanced water retention, including higher field capacity, saturation water content, and wilting point moisture levels. These changes indicate a stronger ability of amended soils to retain water under varying conditions. At the same time, increased SOC was associated with better mechanical performance, reflected in higher resistance to compression and reduced compaction susceptibility.

Soils with greater SOC also showed improved balance between moisture availability and mechanical stability, reducing risks linked to soil deformation under wet conditions. Organic amendments further improved physical resilience by increasing pre-consolidation



pressure while lowering the soil compaction index, indicating improved load-bearing capacity.

Overall, the findings demonstrate that organic inputs, especially biochar at higher application rates, effectively enhance soil physical quality by improving carbon stability, regulating moisture behaviour, and strengthening resistance to compaction. These results support the use of targeted organic amendment strategies to improve soil function and sustainability in intensively managed agricultural systems.

This research is supported by the National Key R&D Program of China (Grant No. 2022YFD1500600) and Liaoning Provincial Natural Science Foundation of China (Grant No. 2024-MS-090).

Comparative analysis of diurnal water use dynamics in two halophytic shrubs under non-saline and saline conditions

Project team: Professor Erik Veneklaas² (project leader; erik.veneklaas@uwa.edu.au), Gaku Sagara², Associate Professor Yoshiyuki Miyazawa³, Associate Professor Sugiura Daisuke²

Collaborating organisations: ¹UWA; ²Graduate School of Bioagricultural Sciences, Nagoya university, Japan; ³University of the Ryukyus, Japan

In southwestern Australia, forage shrubs that tolerate salinity and drought may provide feed in dry summers and autumns. Perennial halophytic shrubs such as *Atriplex nummularia* (C4) and *Rhagodia preissii* (C3) can play an important role in farming systems. The physiological mechanisms underlying their tolerance of drought and salinity are not fully understood. Our study focused on two traits that may contribute to their stress tolerance: (1) the ability to close and open stomata rapidly and (2) the role of stored stem water in buffering diurnal transpiration.

Experiments were conducted in a growth room with controlled temperature, humidity and light conditions at The University of Western Australia in 2024 using pot-grown plants under non-saline and saline (250 mM NaCl) conditions. We measured stomatal conductance under both conditions and evaluated the speed of stomatal closure to fluctuating light environments using portable gas exchange systems. To evaluate the dynamics of stored water in shrubs, we developed and utilised non-invasive small sap flow sensors based on the Heat Ratio Method (HRM), controlled by Arduino-based microcontrollers. We measured sap flow at both the stem base and the upper shoot and investigated if there is time lag between the positions caused by the use of stored water. We also determined capacitance, defined as the change in water content per unit change in tissue water potential to further quantify the capacity to store and release water under non-saline and saline conditions.

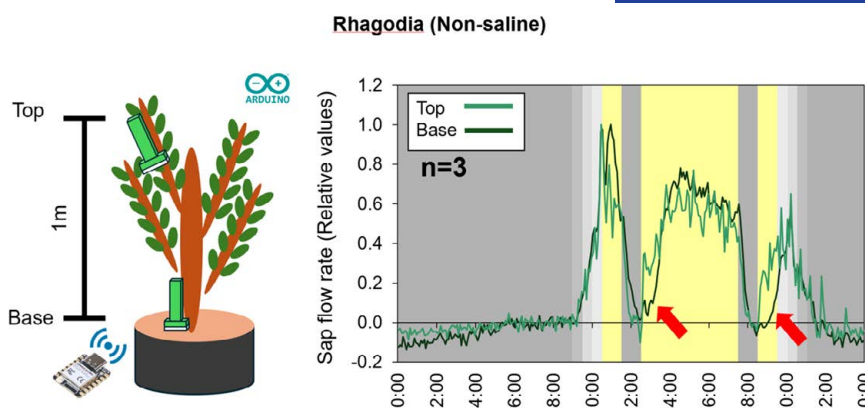
Findings indicate that both species adopt a conservative water-saving strategy with rapid stomatal closure during dark periods to minimise unnecessary water loss. A significant discovery was the delay in sap flow increase at the stem base following light transitions, particularly in *Rhagodia* under non-saline conditions. This delay suggests a reliance on stored water within the shoot to support transpiration. Notably, the estimated contribution of stored water to total daily transpiration was higher under salt stress for both species along with increased capacitance.

The successful implementation of non-invasive sap flow sensors in this study provides a new methodology for investigating the water use dynamics in halophytic shrubs. These findings enhance our mechanistic understanding of how halophytic shrubs coordinate stomatal regulation and internal hydraulics to survive in dry and saline environments.

This research is supported by Professor Veneklaas discretionary funding. Plants were kindly provided by Dr Hayley Norman, CSIRO.



Monitoring plant water use in a controlled environment using custom-built sap flow sensors on the stem top and base.



Diurnal sap flow dynamics at the stem top and base of *Rhagodia preissii* under non-saline conditions, illustrating the temporal lag in water movement at the base.



Western Australian-bred Pink Lady apples growing in an orchard.

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 Leader

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Figure 1. Representative images of cuttings grown at 18°C, 22°C, 26°C (left to right) at 60 DAT.

The function of photoreceptors in warm temperature growth responses of grapevine

Project team: Associate Professor Michael Considine¹ (project leader; michael.considine@uwa.edu.au), Hackett Professor Kadambot Siddique¹, Associate Professor Monika Murcha¹

Collaborating organisations: ¹UWA

Plants have evolved remarkable mechanisms to sense and respond to their surrounding environment, coordinating key stages of growth and development in response to predictable environmental cues. Among these, light and temperature stand out as the most influential signals regulating plant growth throughout the life cycle, from seed germination to fruit ripening.

Beyond its fundamental role in photosynthesis, light serves as a critical environmental signal that plants decode through specialised proteins known as photoreceptors. These include phytochromes, cryptochromes, phototropins, and UVR8, each sensitive to a distinct region of the light spectrum — red, blue, and ultraviolet light, respectively — allowing plants to adjust their growth depending on the light environment.

A particularly important photoreceptor is Phytochrome B (PHYB), which functions as an integrator of both light and temperature signals. In *Arabidopsis*, exposure to elevated ambient temperatures (27–32°C) shifts PHYB from its active to inactive state, triggering a cascade of developmental changes, including stem and petiole elongation, collectively known as thermomorphogenesis. Notably, blue light perceived by cryptochrome 1 (CRY1) can counteract this response by suppressing the activity of a key transcription factor, PIF4, thereby fine-tuning the plant's response to warmth. Similar elongation responses are also observed when plants detect shade,

identified by a reduced ratio of red to far-red light — a phenomenon termed the Shade Avoidance Syndrome (SAS).

This adaptive strategy enables plants to compete for light in dense canopy environments. The Climate Atlas project forecasts a mean increase of 1.2 by 2050 and 2.8 by 2090 across all regions. In addition to temperature rise, Australia has been subjected to severe climatic events like heatwaves, wildfires and altered timing and precipitation levels of rainfall. Grapes grown in Australia are often exposed to high temperatures exceeding 40, which can prevail for several days causing reduced berry development and delayed ripening. High temperatures at flowering can cause crop loss and later in the season retard berry growth and hamper accumulation of sugars and thus reducing yields, delaying harvest, and affecting berry composition. This study investigates the role of phytochrome B (PHYB), a highly conserved photoreceptor, in regulating grapevine morphogenesis under warm ambient temperatures, with the aim of advancing our understanding of how grapevines respond to the thermal challenges posed by a warming climate.

To study the effect of temperature and shade, Homozygous *phyb* and *phya* mutants, along with Col-0 plants as controls, were grown under two temperature regimes (30/23 (day/night) and constant 23) and exposed to either 16 hours light or shade, followed by 8 hours of darkness. Our results reveal that at elevated temperatures (30/23), *phya* is more sensitive to shade, exhibiting both enhanced petiole elongation and delayed flowering, likely due to reduced PHYB activity. By contrast, *phyb* mutants responded more strongly to temperature,

flowering early but still showing petiole elongation in light. At 23, shade exerted stronger effects on flowering and petiole elongation in Col-0 and *phya*, whereas *phyb* consistently displayed longer petioles and early flowering regardless of light regime, indicating reduced sensitivity to shade but heightened responsiveness to temperature.

To investigate the effect of temperature, *Vitis* single-node cuttings were grown under four temperature regimes (18°C, 22°C, 26°C, and 30°C) under controlled low light conditions (30–40 $\mu\text{mol m}^{-2} \text{s}^{-1}$ photosynthetic photon flux density, PPFD). Temperature strongly influenced plant development, with higher temperatures markedly accelerating phenological progression, as evidenced by reduced time to bud burst and attainment of the EL12 stage. In contrast, vegetative traits, including petiole length and internode length, declined with increasing temperature, indicating suppression of elongation growth rather than stimulation. Shoot length showed only a modest and variable increase, suggesting that overall plant growth was less consistently affected. Structural traits, such as petiole angle and chlorophyll content, remained largely stable across the temperature range.

Overall, these findings indicate that elevated temperatures and low light intensities primarily accelerated developmental timing while having limited or negative effects on elongation growth and minimal impact on structural and physiological traits.

This research is supported by CRC-NA, DPIRD and Fresh Produce Group.

Phased Genome Assembly and Structural Variant analysis to decode Rvi6 Mediated Scab Resistance of “Liberty” apple

Project team: Associate Professor Michael Considine¹ (co-project leader; michael.considine@uwa.edu.au), Dr Sultan Mia^{1,2} (co-project leader; sultan.mia@dpiird.wa.gov)

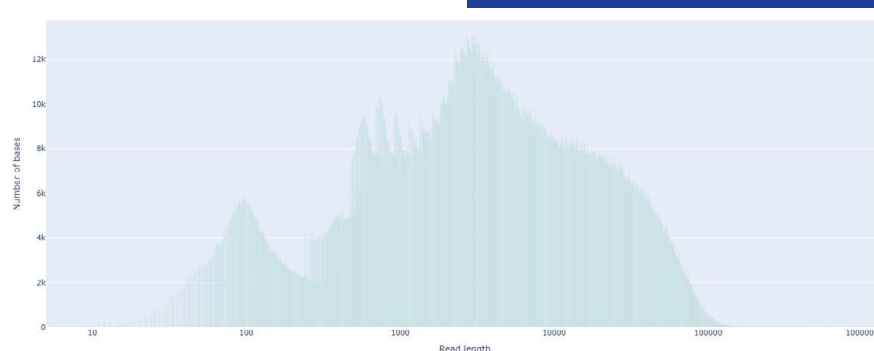
Collaborating organisations: ¹UWA; ²DPIRD

Apple (*Malus domestica*) is one of the most economically important temperate fruit crops worldwide and plays a significant role in horticultural production in Australia. However, apple production is severely constrained by apple scab, caused by *Venturia inaequalis*, which is one of the most destructive diseases of apple. In commercial orchards, management of apple scab typically relies on frequent fungicide applications, increasing production costs and raising environmental and sustainability concerns.

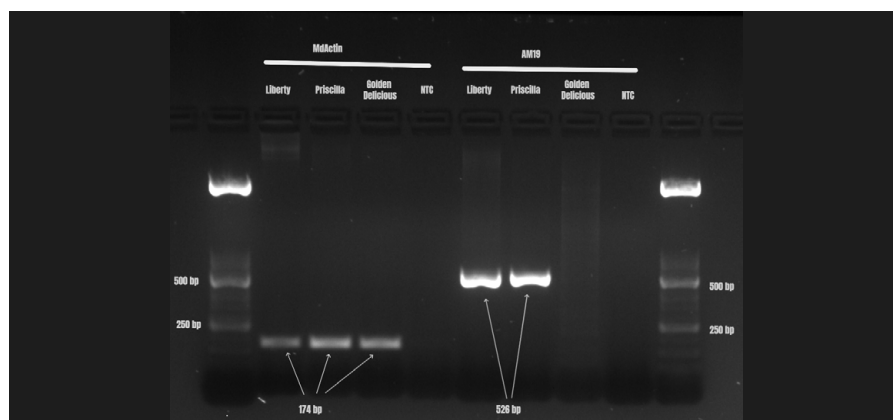
The development and deployment of resistant cultivars offer a promising alternative to intensive chemical control. Among resistance sources, the Rvi6 locus, originally derived from *Malus floribunda* 821, has been widely used in breeding scab-resistant apple cultivars such as ‘Liberty’, ‘Prima’ and ‘Priscilla’. Several modern apple cultivars (for example, CIVG198 (Modi) = Gala x Liberty and MN80 (First Kiss®) = Honeycrisp x Liberty) has ‘Liberty’ in their pedigree to integrate disease resistance with better fruit quality traits. Despite its importance, the genomic architecture and structural variation, especially the Rvi6 region, have not been characterised yet.

This project aims to generate a haplotype-resolved genome assembly of the scab-resistant ‘Liberty’ apple cultivar using Oxford Nanopore long-read sequencing technology and to discover structural variant to characterise the Rvi6 resistance locus. Long-read sequencing enables improved assembly continuity and accurate resolution of repetitive and structurally complex regions, providing deeper insights into resistance gene architecture.

In 2024, leaf samples of ‘Liberty’ were collected from the Manjimup Horticulture Research Centre, DPIRD in Manjimup WA. Validation with flanked marker confirmed the presence of the Rvi6 locus in the



Weighted histogram of Oxford Nanopore PromethION read lengths for *Malus domestica* (‘Liberty’) after log transformation. A dominant peak in the long-read region (10–30 kb) and a smaller peak of shorter fragments (~100 bp), indicating overall high-quality long-read sequencing with minor fragmentation.



Agarose gel electrophoresis showing PCR amplification of *MdActin* (174 bp) and *AM19* (526 bp) in apple cultivars. Lanes represent *Liberty*, *Priscilla* (positive control), *Golden Delicious* (negative control), and NTC (no template control). The *MdActin* gene (174 bp) was successfully amplified in all samples except NTC, confirming DNA quality. The *AM19* marker (526 bp), associated with the Rvi6 resistance locus, produced clear bands in *Priscilla* and *Liberty*, while no amplification was observed in *Golden Delicious* and NTC. DNA ladder (50 bp) is shown on both sides for size estimation.

selected samples. High-molecular-weight DNA was successfully extracted and subjected to sequencing using DPIRD’s Oxford Nanopore PromethION platform, generating long-read data with an N50 read length of approximately 26 kb. Initial bioinformatics workflows have been established for read quality control and basecalling. Ongoing analyses include genome assembly using Hifi-ism ONT, followed by polishing with Illumina reads, Structural and functional annotation.

The Rvi6 locus in ‘Liberty’ will be characterised and compared with previously reported resistant cultivars such as ‘Prima’, and ‘Priscilla’ as well as with the

susceptible reference genome of ‘Golden Delicious’. This comparative analysis will provide insights into sequence variation, gene structure, and potential mechanisms underlying resistance.

The outcomes of this project will contribute to a better understanding of scab resistance in apple and provide valuable genomic resources for breeding programs. Ultimately, this work supports the development of durable disease-resistant cultivars, reducing reliance on fungicides and promoting more sustainable apple production systems.

This research is supported by Australia Awards, DPIRD and UWA.



Preparation for scanning of experimental grapevine (*Vitis vinifera* cv. Thompson Seedless) on TraitFinder.

Metabolic regulation of inflorescence development and fate in grapevine

Project team: Associate Professor Michael Considine¹ (project leader; michael.considine@uwa.edu.au), Hackett Professor Kadambot Siddique¹, Professor John Considine¹, Dr Aneta Ivanova¹, Pragya Poudel¹

Collaborating organisations: ¹UWA; ²CRC Innovating the Growth of Tropical Table Grapes

Grape plasticity to climate makes grapevine a compelling crop for viticulture expansion to Northern Australia, as it shows prospects for growth in the region. This research explores the opportunities and limitations associated with that expansion. As *Vitis vinifera* was domesticated in a temperate climate, expansion to the tropics is associated with high-temperature stress and a lack of photoperiodic variation, which affect floral initiation and development in grapevine - processes that are critical to yield.

This research elucidates the role of temperature in regulating grapevine floral development in low-latitude climates. Field investigations across climatically distinct Western Australian sites: Broome, Carnarvon, Swan Valley, and Hamel, using microscopy imaging, revealed that

temperature imposes an upper threshold for reproductive initiation. Buds from the tropical Broome site exhibited significantly lower fruitfulness and less developed floral initials compared to the other sites, under a common genotype and similar production methods.

Further controlled environment experiments during budburst suggested that increasing temperature reduces inflorescence mass, which might be associated with carbon depletion at higher temperatures.

The research is also incorporating antioxidant mutants that are currently being investigated under elevated ambient temperatures to explore whether antioxidant capacity can mitigate the effects of high temperature on floral development.

Overall, the combination of field and controlled environment studies, together with the incorporation of phenotypic and molecular approaches, will provide critical information on the temperature regulation of grapevine floral development. This will serve as a knowledge base for viticulture expansion in Northern Australia and for warmer climate change scenarios in Southern Australia in the future.

This research is supported by UWA and CRC Innovating the Growth of Tropical Table Grapes.



Grapevine (*Vitis vinifera* cv. Thompson Seedless) under controlled environment conditions.

Molecular characterisation and genotyping of S-RNase Alleles in apple (*Malus × domestica*): From gene structure to breeding applications

Project team: Associate Professor Michael Considine^{1,5} (project leader; michael.considine@uwa.edu.au), Dr Sultan Mia^{1,5}, Associate Professor Nicolas Taylor¹

Collaborating organisations: ¹UWA; ²ARC PBAF; ³The University of Queensland; ⁴WAAA; ⁵DPIRD

This PhD research addresses critical knowledge gaps in apple (*Malus × domestica*) gametophytic self-incompatibility (GSI), a major constraint for breeding and commercial production. Current S-genotyping methods are labour-intensive and low-throughput; S-allele diversity in breeding germplasm remains poorly documented, and the genomic basis of superior pollination performance in elite crabapple pollinizers has never been investigated.

The research tackles these challenges through three integrated experiments: 1) developing a comprehensive S-RNase database, characterising them and developing high-throughput KASP genotyping panel, 2) conducting comprehensive S-genotyping of Manjimup Horticultural Research Institute (MHRF), DPIRD, WA germplasm, and 3) generating

the first chromosome-level genome assembly for *Malus × baccata* ‘Dolgo’, an elite pollinizer crabapple.

Since commencing candidature on 17 July 2025, substantial progress has been achieved across all objectives. For Experiment 1, a comprehensive S-RNase characterisation pipeline has been completed across multiple analytical phases: sequence curation of 37 S-RNase sequences across three *Malus* species (*M. domestica*, *M. spectabilis*, and *M. transitoria*), multiple sequence alignment with conserved region annotation (C1–C5, RHV), phylogenetic reconstruction using maximum likelihood (IQ-TREE), neighbour-joining, and RAXML-NG approaches, pairwise Ka/Ks selection pressure analysis, and structural analyses including AlphaFold2 structure prediction for all alleles via ColabFold, TM-align structural superposition, N-glycosylation site prediction, and signal peptide annotation. Phylogenetic tree visualisation via iTOL and PAML site-model positive selection analysis remains in progress. For Experiment 2, sample collections from MHRF have been completed, securing approximately 300 apple accessions

representing diverse germplasm, and a strategic plan for S-genotyping analysis has been prepared. For the Dolgo genome project (Experiment 3), major milestones have been achieved including Oxford Nanopore sequencing using DPIRD’s PromethION platform, hifiasm assembly with ONT data (721 Mbp, N50 11.5 Mbp, BUSCO 99.1 per cent), Medaka polishing, and reference-guided scaffolding using RagTag with a newly published chromosome-level *M. baccata* genome (GCA_054553115.1, January 2026) to achieve a chromosome-level assembly with 17 scaffolds (N50 37 Mbp, 90 per cent genome placed).

Together, these outputs will provide the apple breeding community with practical tools for pollination management, a deeper understanding of self-incompatibility allele diversity, and valuable genomic resources for a widely used polliniser cultivar.

This research is supported by UWA, ARC PBAF and DPIRD.



Collection of apple leaf samples from Manjimup Horticultural Research Institute, DPIRD, WA.



Fruits of ‘Dolgo’ (*Malus × baccata*).



Participation of Sadia in the sensory evaluation of hop varieties at HPA, Tasmania.

Sadia's visit to the experimental hop trial site at Bushy Park Estate, Tasmania.

Investigation of hop off-flavour development in post-harvest conditions using metabolomics and genetics approach

Project team: Associate Professor Michael Considine¹ (project leader; michael.considine@uwa.edu.au), Associate Professor Gavin Flematti¹, Dr Simon Whittcock², Sadia Haque Tonny¹

Collaborating organisations: ¹UWA; ²Hop Products Australia

Hop (*Humulus lupulus*) is a diploid, dioecious perennial plant of the Cannabaceae family whose female cones contain glandular trichomes (lupulin glands) at the bracteole bases that accumulate terpenophenolics and secondary metabolites. Hops value for the use of volatile flavours they impart to the beer has increased recently. The brewing industry acts as the core driver of the hop sector, contributing to 97 per cent of beer production.

The last 15 years have seen a significant consumer shift of demand toward aroma forward beer by the craft brewing industry using aroma or 'dual-purpose' hops during dry hopping. Dry hopping results in selective extraction and retention of a different suite of bio- and aroma active components. Key metabolites specifically targeting derivatives of hop alpha (α) and beta (β) acids & polyphenols undergo physical and chemical composition changes during post-harvest storage and processing and in beer between production and consumption. This

ultimately reduces beer quality. In the case of hops, oxidative and thermal instability during post-harvest handling (kilning, conditioning, baling, transport and storage) may result in the development of unpleasant flavor in beer. This directly reduces the sensory quality of beer, and results in substantial economic losses for brewers. Hop Products Australia (HPA) has developed several world-leading hop varieties, including Galaxy®, Ella®, Enigma®, and Eclipse®, with Galaxy recognised as one of the top varieties globally. However, the biochemical and genetic basis underlying its susceptibility remains unknown. The variation in candidate metabolites among different hop varieties under oxidative and thermal degradation needs to be systematically investigated to understand how metabolite changes contribute to off-flavor development in beer.

An integrated metabolomics approach will help develop a validated assay to identify and quantify off-flavor metabolites, specifically targeting derivatives of hop alpha (α) and beta (β) acids & polyphenols. Reverse phase liquid chromatography (RP-HPLC), liquid chromatography (LC), and mass spectrometry (MS) will be coupled together for targeted and untargeted metabolomics. Coupled LC-MS/MS provides the precision to distinguish

between oxidative and auto-degradation metabolites with potential to produce off-flavours and identification of chemical fingerprints. Thus, the metabolite profiling of different hop varieties with forced aging combined with metabolomic and sensory analysis will help to understand hop-derived impact on beer flavor and aroma profile.

The major aim of this study is to develop and validate metabolomics assay for identifying oxidation-related secondary metabolites responsible for hop off-flavour development during storage. Also, the project will focus on investigating the genetic basis of metabolite stability through QTL mapping and heritability analysis in hop breeding populations. Improved understanding of the biochemical processes of hop bitter acid oxidation and genetic basis may provide an opportunity to manage the anomalies in existing varieties and production systems for the brewers. Also, selection for improved post-harvest oxidative stability in hop breeding and new cultivar development is crucial to understand.

This research is supported by ARC Industrial Transformation Training Centre in PBAF and HPA.

Comparative transcriptome profiling of apple cultivar Cripps Pink (Pink Lady™) and its yellow mutant (Yellow Cripps Pink) to reveals key drivers of skin colour variations

Project team: Hackett Professor Kadambot Siddique¹ (project leader; kadambot.siddique@uwa.edu.au), Dr Sultan Mia² (project leader; sultan.mia@dpiird.wa.gov.au), Associate Professor Michael Considine¹, Md Golam Azam¹

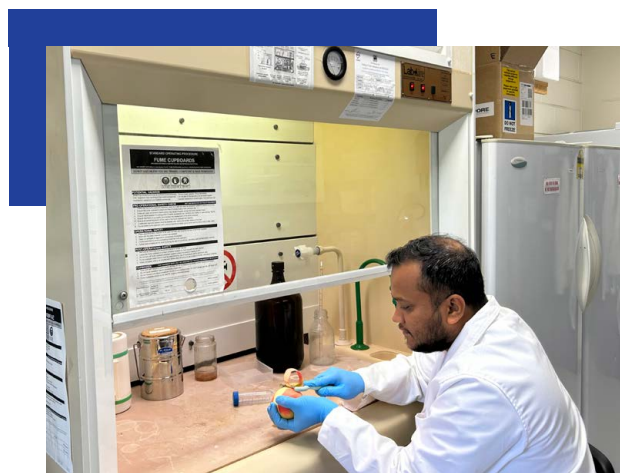
Collaborating organisations: ¹UWA; ²DPIRD

Apple cultivar Cripps Pink (CP) is the most popular apple cultivar released by the Australian National Apple Breeding Program (ANABP) of the Department of Primary Industries and regional Development (DPIRD). Its fruits branded as Pink Lady™ have characteristic oblong-conical shape and pinkish-red blush on fruit skin. Since its release several bud sports/ natural mutants of CP with variable traits have been patented. One such mutant named Yellow Cripps Pink (YCP) produces fruit with a green to yellow skin with no blush. These will serve as ideal materials for investigating molecular mechanism of skin coloration.

Understanding the basis of this colour variation requires examining gene expression during fruit development. Transcriptome analysis enables the identification of actively expressed genes and provides insight into the regulatory mechanisms underlying phenotypic differences. In apple, red skin colour is primarily associated with the accumulation of anthocyanins, which are synthesised through a well-characterised biosynthetic pathway.

This pathway involves a series of structural genes, including PAL, 4CL, CHS, CHI, F3H, DFR, ANS, and UFGT, as well as regulatory genes such as MYB transcription factors that control their expression. Variation in the activity of these genes can lead to differences in pigment accumulation and, consequently, fruit colour.

The aim of this study is to identify key genes and expression patterns that differ between Cripps Pink and its mutant YCP across different stages of fruit



development. To achieve this objective, CP and YCP was grafted onto same tree so that both could grow under the same microclimatic conditions, thereby minimising environmental variation and ensuring that any observed differences are primarily genetic.

This research is supported by the UWA international fee scholarship, Australian Government Research Training Program Stipend Scholarship and John Cripps Horticulture HDR Top-Up Scholarship.

Top image: Md Golam Azam carefully peeling apple skin under a fume hood for RNA extraction as part of his research on the genetic basis of skin colour in Cripps Pink apple.

Bottom image: Cripps Pink (CP) and Yellow Cripps Pink (YCP) apple cultivars at the ANABP orchard, DPIRD, Manjimup. (A) Full tree showing the grafts of CP and YCP. (B) YCP fruit cluster showing uniform yellow-green colouration. (C) CP fruit cluster displaying the distinctive red-pink blush.



Novel agronomic practices to achieve productive and profitable viticulture in northern Australia: Part 1 - IPM

Project team: Associate Professor Michael Considine¹ (project leader; michael.considine@uwa.edu.au), Professor John Considine¹, Dr Julia Grassl^{1,2}, Dr Chris Ham², Dr Kiran Mahat², Aimee Grieves², Carla Milazzo²

Collaborating organisations: ¹UWA; ²DPIRD; ³Shin-Etsu Chemical Co. Ltd Japan; ⁴Bloom Fresh Intl; ⁵Bumbback and Sons, Carnarvon; ⁶P. Nuich, Swan Valley; ⁷Charles Sturt University; ⁸NSW Dept of Primary Industries and Regional Development; ⁹Shin Etsu Chemical Company, Japan

The pest moth *Spodoptera litura*, or 'Cluster Caterpillar', is being established as a key element in the development of sustainable, profitable cropping systems in northern Western Australia. Recently, the pest has been spread south to the Carnarvon Horticultural Region, where significant problems are being caused in a broad range of perennial and annual vegetable crops. In collaboration with Shin Estu Chemical Company, a series of trials has been initiated to determine the efficacy of their mating disruption technology under tropical conditions.

A preliminary test of a small number of pheromone-releasing lures was found to be remarkably effective in regulating mating within the area defined by the presence of the lures. Additionally, control longevity was observed to extend beyond six months, confirming that the lures remained effective despite high temperature and humidity.

Consequently, a commercial-scale importation of lures has been successfully applied for to APVMA as a prelude to providing the evidence that will be required should registration be sought by the company. These trials are currently in progress.

Secondarily, technology for evaluating pesticide resistance within moth populations has been developed in collaboration with colleagues in the NSW DPIRD. Resistance to some of the widely used pesticides has been confirmed, and advice to growers is being modified accordingly. The high fecundity of the moth in northern Australian climates, which enables a short life cycle and numerous generations, indicates that reliance on IPM will need to be adopted by the industry.

Above left: A pheromone-releasing stick in place to test the effectiveness of disrupting the mating cycle of *Spodoptera litura*.

Above right: A moth trap for monitoring moth counts during the season and the effect of the mating disruption.

Local predators have been identified that, under experimental conditions, are highly effective, offering the prospect of lower pesticide input and greater certainty of economic success.

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 Considine¹ (project leader; michael.considine@uwa.edu.au), Professor John Considine¹, Dr Julia Grassl^{1,2}, Dr Chris Ham², Aimee Grieves², Pragya Poudel¹, Noor Shaik¹, Wenyi Xu¹, Hugo Campbell¹

Collaborating organisations: ¹UWA; ²DPIRD; ³Bloom Fresh Intl; ⁴Bumback and Sons, Carnarvon; ⁵P. Nuich, Swan Valley; ⁶Charles Sturt University

The intent of this project is to support the development of high value horticultural crops in northern Australia. For example, the estimated value on a per hectare basis of horticultural cropping in Carnarvon is estimated to be in the region of \$70,000, while cropping in the Ord River Scheme is about \$5000. Low latitudes also offer the prospect of 'out-of-season' production, enabling import replacement and the potential of 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.

It is surprising that there is so little ecophysiological research published regarding the adaptation of crops that originated in temperate or Mediterranean-like climate zones to cultivation in lower latitudes. This despite successful cultivation of some. Thus, it has been known since the 17th century that grapes could be cultivated in Venezuela and managed to crop two to three times a year. Dormancy is not a requirement for reproduction in the grape. However, a cycle needs to be forced and yields are low. Even two crops a year fails to reach the annual yield of a vine growing in a conventional region.

High temperature limitation of inflorescence development in the year of initiation (the previous cropping cycle) has been identified as one key factor, with the impact of high temperature on photosynthetic efficiency as another, and carbon and nitrogen reserves as a third, arising from reduced net photosynthesis and a marked shift in growth allocation from root to shoot. In a conventional crop, 70 per cent of reserves are located in the roots. The low root mass in vines grown under tropic-like conditions inevitably constrains the next growth cycle.

This project is supported by a pioneer of intensive, large scale, horticultural production in the Kimberley, Fresh Produce Group (FPG). It is also supported by CRC- Developing Northern Australia and DPIRD.



Top right: Harvesting of vines from a controlled environment experiment to simulate a Mediterranean vs tropical climate for the purpose of investigating physiology and carbon partitioning.

Bottom right: Collection of roots for monitoring of starch levels in different plant parts – featuring Aimee Grieves (DPIRD).



Farmer working in the field on a tractor 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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Associate Professor Andrew Guzzomi and Dr Stuart Watt at the Agritechnica Trade Fair.



The CEI:AgER team presenting to researchers from Global Research Institute for Mobility in Society (GREMO) at Nagoya University.

Centre for Engineering Innovation: Agriculture & Ecological Restoration

Project team: Associate Professor Andrew Guzzomi¹ (project leader; andrew.guzzomi@uwa.edu.au), Professor Michael Walsh^{1,2}, Dr Todd Erickson¹, Trent Mahony, Dr Monte Masarei¹, Dr Wesley Moss¹, Dr Luke Omoarelojie¹, Dr Stuart Watt¹, Lee Hunt¹, William Richards¹, Stephanie Lye¹, Eve McCallum¹, Ruby Wiese¹, Dr Harrison Caddy¹, Yuval Juran¹, Dr David Merritt³, Dr Alison Ritchie^{1,3}, Miranda Slaven^{1,4}

Collaborating organisations: ¹UWA; ²Charles Sturt University; ³Kings Park Science; ⁴DPIRD

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 2025, CEI:AgER:

- Dr Stuart Watt and Associate Professor Andrew Guzzomi attended the Land. Technik Conference and the Agritechnica trade fair in Hanover, Germany

- Associate Professor Guzzomi, Dr Harrison Caddy, Dr Wesley Moss, Dr Stuart Watt travelled to Nagoya University, a partner institution of UWA, to explore collaboration opportunities
- Associate Professor Guzzomi gave a keynote speech for the opening address of the International Society for Seed Science Conference 2025. Associate Professor Guzzomi, Dr Alison Ritchie and Dr Todd Erickson presented their research and PhD candidates Stephanie Lye and Ruby Wiese presented posters, resulting in Ms Lye winning the Marc Cohn Best Student Poster Award. The ISSS conference included a field tour of the Centre and the official launch of the spinout company Emergence Ecotech.

This research is supported by UWA.



Demonstration of the rotary tillage prototype to cotton farmers in the Ord River region, December 2025.

Mechanical in-crop weed control

Project team: Associate Professor Andrew Guzzomi¹ (project leader; andrew.guzzomi@uwa.edu.au), Professor Michael Walsh², Dr Carlo Peressini¹, Dr Stuart Watt¹

Collaborating organisations: ¹UWA; ²Charles Sturt University

The aim of this project, funded by the Department of Agriculture, Fisheries and Forestry, is to develop a mechanical weed control system for use in-crop in large-scale row-crop farming systems. With skills in engineering and weed science, the team is working with leading farmers/innovators, industry partners and machinery manufacturers in WA, NSW and QLD to devise adoptable 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.

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 aims to add another tool to the weed control arsenal, that allows for non-chemical methods by mechanically removing weeds from the field in-crop.

Highlights for 2025 include:

- In February, two pre-commercial scale test rigs were sent to Toowoomba (QLD) for in-crop testing in sorghum and for demonstrations to local farmers. A follow-up trip took place in March to nearby location for more demonstrations and an interview with Weed Smart.

- The Department of Agriculture, Fisheries and Forestry (DAFF) in-crop targeted tillage project officially finished in March, 2025, with a meeting with the industry advisory panel. In July, two field trips to Northam and Wongan Hills, WA, took place to test the electric rotary tillage prototype in wheat crops as part of ongoing PhD research undertaken by Miranda Slaven with AHRI and DPIRD. In September, the team travelled to Wagga Wagga to facilitate another round of weed kill efficacy trials, hosted at CSU.
- In November, a final field trip to Kununurra saw both the UWA Weed Chipper and new electric rotary tillage rigs demonstrated to cotton farmers in the Ord River region as part of a Northern Australia Crop Research Alliance (NACRA) project.

With the testing and milestones complete for the DAFF project, ongoing prototype developments looking to integrate learnings from the DAFF project and advance functionality and performance is being conducted as part of research and development funded by Demagtech.

This research is supported by UWA and DAFF.



7-tine rotary tillage prototype testing in Toowoomba, March 2025.



Luke Omoarelojie monitoring plant health for a trial on seedling pellet and bio stimulant efficacy in Jarrah forest rehabilitation.

Restoration Engineering Seed Technology Deployment Program and Australian Seed Scaling Initiative

Project team: Dr Todd Erickson¹ (project leader; todd.erickson@uwa.edu.au), Associate Professor Andrew Guzzoni¹, Dr Monte Masarei¹, Dr David Merritt^{1,7}, Dr Luke Omoarelojie¹, Dr Harrison Caddy¹, Eve McCallum¹, Stephanie Lye¹

Collaborating organisations: ¹UWA; ²BHP; ³Alcoa; ⁴CRC TiME; ⁵Botanic Gardens and Parks Authority; ⁶Department of Biodiversity, Conservation and Attractions; ⁷Kings Park Science

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. These two projects work to develop technology and systems to process, enhance and more efficiently precision sow diverse mixes of wild-collected seeds.

This 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 in the project team at CEI:AgER collaborate extensively with seed scientists at Kings Park Science.

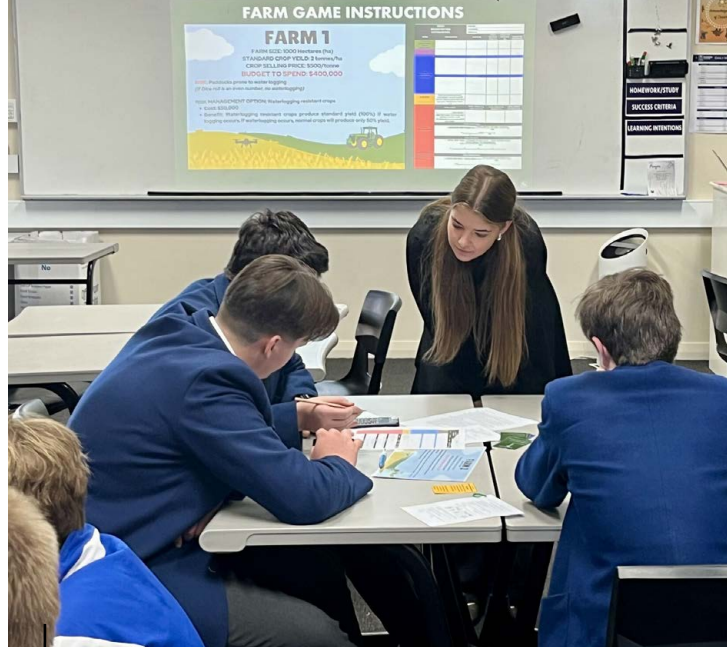
In 2025 the Restoration Engineering Seed Technology Deployment Program focussed on testing a machine dubbed “The Mechanical Cow”. This device distributes a topsoil slurry embedded with seeds with the aim of efficiently placing valuable topsoil only where it is needed, surrounding the seeds. The slurry can also contain biostimulants and soil amendments to further aid germination, emergence and plant establishment. A field trial was installed at BHP’s Yandi seed production area, testing a method that has shown success in the lab, in a real-world mining setting. Data collection and analysis is ongoing (Figure 1).

The Australian Seed Scaling Initiative is ending in 2026 with 2025 activities focussing on monitoring of trials installed throughout the project. In particular, monitoring and analysis seed pelleting data (Figure 2) is showing the success of certain biostimulants, but also the need to bury pellets to ensure a slow breakdown of the pellet material, allowing biostimulants to be available to the plants for longer and ensuring seeds remain covered whilst going through the germination process.

This research is supported by UWA, BHP and CRC TiME.



Triodia pungens (soft spinifex) seedlings emerging from “seed pats” produced by the “Mechanical Cow”.



Thesis student Kate Miller running a workshop for high school students at Mazenod College. Students are playing a board game, developed by Kate, to increase their awareness of technology in agriculture.



CEI:AgER Team at Future Ag Expo in Melbourne as part of GRDC Grain Automate Alley.

Grain Automate - Developing capability, awareness, and preparedness for autonomy in the tertiary education sector

Project team: Associate Professor Andrew Guzzomi¹ (co-project leader; andrew.guzzomi@uwa.edu.au), Dr Wesley Moss¹ (co-project leader; wesley.moss@uwa.edu.au), Dr Stuart Watt¹, Alysia Kepert¹, Emeritus Professor Graeme Martin¹, Dr Gustavo Alckmin¹, Professor Marit Kragt¹, Associate Professor James Fogarty¹, Karen Eyles¹

Collaborating organisations: ¹UWA; ²Australian Government Department of Education

The Grains sector is changing radically, with technology affecting every aspect: producers, logistics, manufacturing, marketing, and export. In response the Grains Research and Development Corporation (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: Developing capability, awareness, and preparedness for autonomy in the tertiary education sector.

This requires supporting education and training on two fronts: i) prepare the workforce on the emerging technologies; ii) address the massive shortage of new

professionals. CEI:AgER is developing micro-credentials to meet these needs through: i) developing educational material to upskill tertiary students and workforce; and ii) 'training the trainers', to upgrade secondary teachers so they can teach new agriculture curricula and prepare and excite students about the future of agriculture.

In 2025, the Agriculture Technology microcredential launched with fee-free places sponsored by the Federal Government's Microcredential Pilot Scheme. 78 learners with background across engineering, agricultural science, industry, education and other diverse fields took place in the course. Learnings from this pilot course are informing other microcredentials launching in 2026.

Alongside other initiatives (e.g. student events) this project is supporting 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. 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 are being deployed through UWA's established "UWA Plus" micro-credential framework.

The project launched in 2024 and is 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. Building on tech scouting in Italy that encompassed a visit to EIMA Agricultural Machinery conference in Bologna and meetings with Case New Holland in 2024 and 2025 included AgriTechnica (Germany) and Landtechnik conference.

A key component of this project is building the talent pipeline right from primary and secondary schools. CEI:AgER has with secondary schools across the state to support agricultural technology education and to generate awareness of the exciting challenges and opportunities in agriculture. UWA thesis students have completed projects studying agricultural technology awareness in secondary schools and developing gamified activities to help increase it. Associate Professor Guzzomi also spent time during his 2025 sabbatical as a Visiting Scholar at Bunbury Cathedral Grammar School, interacting with students and supporting the school in integrating agriculture into the STEM curriculum.

This research is supported by GRDC.

Evaluation of the agronomic performance of novel methods for sustainable subterranean clover (*Trifolium subterraneum* L.) seed harvesting



Swathing subterranean clover with a modified peanut digger on a commercial farm in Pingelly, Western Australia in October 2025.



Ruby Wiese presenting her PhD research at the 2025 IOA Postgraduate Showcase.

Project team: Ruby Wiese¹ (project leader; ruby.wiese@research.uwa.edu.au), Associate Professor Andrew Guzzomi¹, Professor Megan Ryan¹, Associate Professor Phillip Nichols¹, Dr Wesley Moss¹

Collaborating organisations: ¹UWA

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.

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.

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.

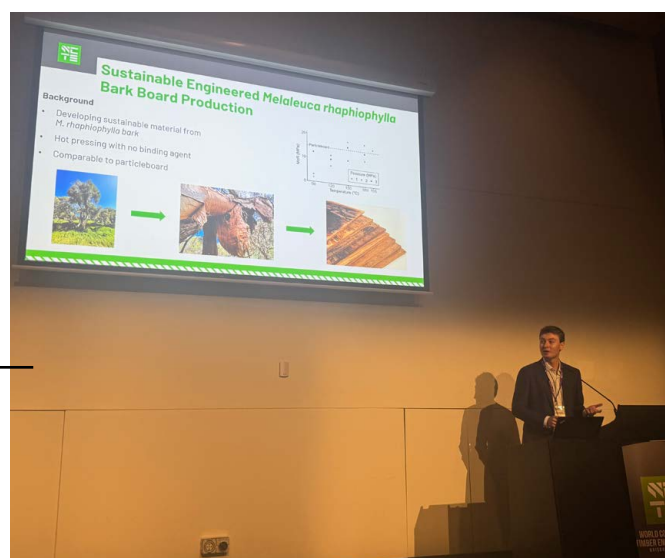
In 2025, Ms Wiese presented at the IOA Postgraduate Showcase. She also published results from her PhD project in "Swathing subterranean clover (*Trifolium subterraneum*) does not suck: a promising alternative to vacuum seed harvesting" in Crop & Pasture Science.

This research is supported by UWA, AgriFutures Australia, the Australian Government Research Training Program Stipend, and an AW Howard Memorial Trust Research Fellowship.

William Richards presenting his poster at the World Conference on Timber Engineering 2025.



Presenting at the World Conference on Timber Engineering 2025.



Melaleuca bark as a sustainable engineered wood product

Project team: William Richards¹ (project leader; william.richards@research.uwa.edu.au), Associate Professor Andrew Guzzomi¹, Dr Monte Masarei¹, Professor Xiao Hu¹

Collaborating organisation: ¹UWA

A new sustainable engineered wood product (EWP) 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.

Following on from promising early results, the project has continued to hone the properties of the EWP explored the potential to utilise mycelium to further enhance the composite properties. Research into harvest conditions of bark was shared at World Conference on Timber Engineering in June 2025.

This research is supported by UWA.

Comparing wheat growth under high and low light intensity in controlled environment via digital and manual phenotyping

Project team: Associate Professor Nicolas Taylor^{1,2} (project leader; nicolas.taylor@uwa.edu.au), Dr Agyeya Pratap^{1,2}

Collaborating organisations: ¹UWA; ²APPN; ³GRDC

This project investigates how varying light intensities in controlled environments influence wheat growth and evaluates the effectiveness of digital phenotyping technologies compared with traditional manual measurements. The study combines controlled environment experimentation, high-throughput 3D-multispectral imaging, and approaches to generate a comprehensive understanding of plant responses to light stress and to validate new methods for rapid phenotypic assessment.

Light is a critical environmental factor shaping plant morphology, physiology, and biomass accumulation. Wheat, being a major global crop, exhibits substantial variation in growth depending on light availability. As modern breeding and

controlled environment crop research increasingly rely on accurate and repeatable measurements of plant traits, there is a growing need for scalable, non-destructive phenotyping tools. Digital phenotyping platforms, such as 3D-multispectral scanning systems, offer the potential to capture structural and physiological traits more efficiently than manual methods. However, rigorous validation is required to ensure that digital measurements correspond well with conventional benchmarks.

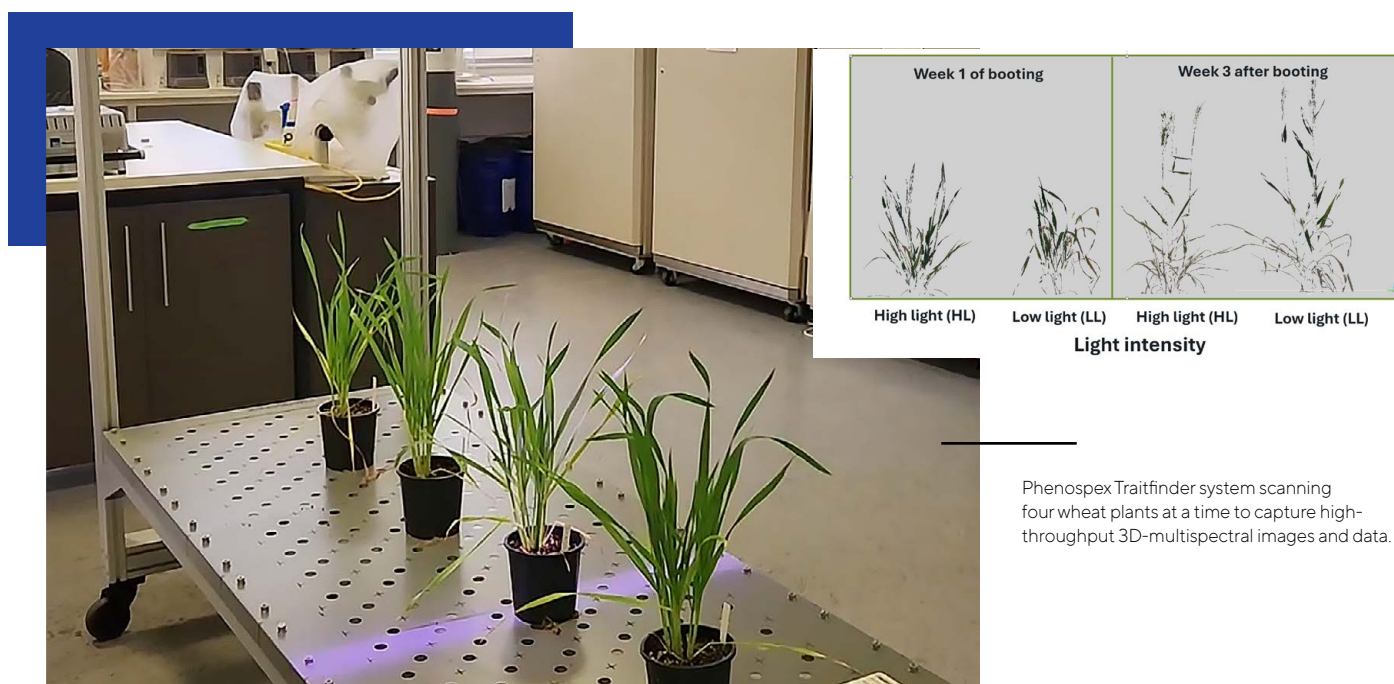
The experiment compares wheat plants exposed to two contrasting light treatments: a high-light (HL) condition at $380 \mu\text{mol m}^{-2} \text{s}^{-1}$ and a low-light (LL) condition at $150 \mu\text{mol m}^{-2} \text{s}^{-1}$. Plants are grown in controlled settings, and their growth trajectories are assessed using both manual approaches, such as leaf area measurements, chlorophyll readings, and biomass recording, and digital methods via the Phenospex Traitfinder, a 3D-multispectral scanning system. The

Phenospex Traitfinder system generates point clouds and trait datasets (e.g., height, projected leaf area, digital biomass, and spectral indices). A timeline-based sampling strategy ensures consistent tracking of trait development.

Preliminary results visually and statistically compare trait differences between HL and LL treatments. Expected outcomes include greater biomass accumulation and grain yield in plants exposed to high light, confirming physiological advantages under stronger illumination.

The study aims to conclude whether digital phenotyping is a robust tool for trait extraction in lightresponse experiments and whether Phenospex Traitfinder can reliably predict novel or complex traits. Ultimately, this work contributes to developing highthroughput, scalable phenotyping pipelines for controlled environment research and crop improvement.

This research is supported by APPN, NCRIS, UWA, GRDC and the WA Government.





A preliminary handheld prototype spectrometer instrument. This is the initial product for commercial release by the partnership between MRG and Magic Wavelength.

Clear differences in wheat growth under low light intensity compared to high light intensity

Project team: Professor Lorenzo Faraone¹ (project leader; lorenzo.faraone@uwa.edu.au), Professor Dilusha Silva¹, Professor Charlie Musca¹, Professor Gilberto Umana Membreno¹, Dr Michal Zawierta¹, Dr Hemendra Kala¹, Dr Gurpreet Gill¹, Ms Yan Liu¹, Dr Kevin Fynn², Dr John Siliquini²

Collaborating organisations: ¹UWA; ²Magic Wavelength Pty Ltd

The Microelectronics Research Group (MRG) at the School of Engineering is accelerating commercialisation of its revolutionary MEMS spectrometer-on-a-chip technology for agricultural applications. Image 1 shows a manufactured MEMS spectrometer chip, in a metal package, ready for system integration. The spectrometer device itself is the tiny squares structure, at the centre of the chip, within the metal package. The Australian 10c coin in the image gives an appreciation of how small these spectrometers really are.

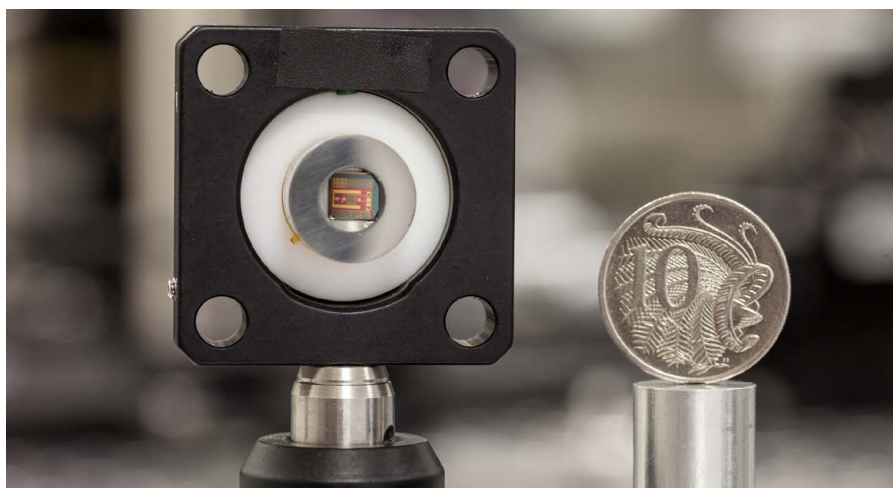
This tiny spectrometer chip weighs less than a gram, consumes almost no power, and is highly robust and ideal for an on-farm instrument. In comparison with benchtop spectrometer instruments, this spectrometer represents a major step-change in size, weight, power, and cost, as well as providing a rugged instrument that is suited to application on the paddock.

Funded by an Australian Economic Accelerator Ignite project and supported by advanced microfabrication facilities at the Australian National Fabrication Facility (ANFF), the team is working closely with commercial partner Magic Wavelength Pty. Ltd. to bring compact, high-performance spectrometers into real-world agricultural use. Magic Wavelength is a Perth-based AgTech engineering and technology start-up with a focus to bring innovative and low-cost optical sensing solutions to the consumer and industrial markets.

While eventually aiming for drone-based applications, the first product in Magic Wavelength's spectrometer lineup is a low-cost hand-held instrument (Image 2) for retail sales. The instrument will measure

the infrared spectrum of a plant and allow assessment of the health of the plant and what treatments are needed. The price-point for this instrument is targeted to allow volume deployment on farm, as well as individual unit purchases for gardening enthusiasts. This price point will also make it affordable for farmers in developing nations, where this technology stands to make substantial impact both for improving yield and for minimising environmental impact.

This research is supported by the ANFF (facilities funding), and research and development funding from Australian Economic Accelerator, ARC, GRDC and DARPA.



A packaged MEMS spectrometer chip forms the core of the commercialised prototype instrument. The spectrometer chip is visible within the metal can package. The 10c coin is presented for scale.



Consumers purchasing locally grown produce at a farmers' market.

6

Agribusiness Ecosystems

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

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

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

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

Here we provide highlights of research and training activities delivered through the Agribusiness Ecosystems theme in 2025. Our research focus contributes to the realisation of the 2030 Agenda of Sustainable Development.

Theme Leaders

Associate Professor Amin Mugera

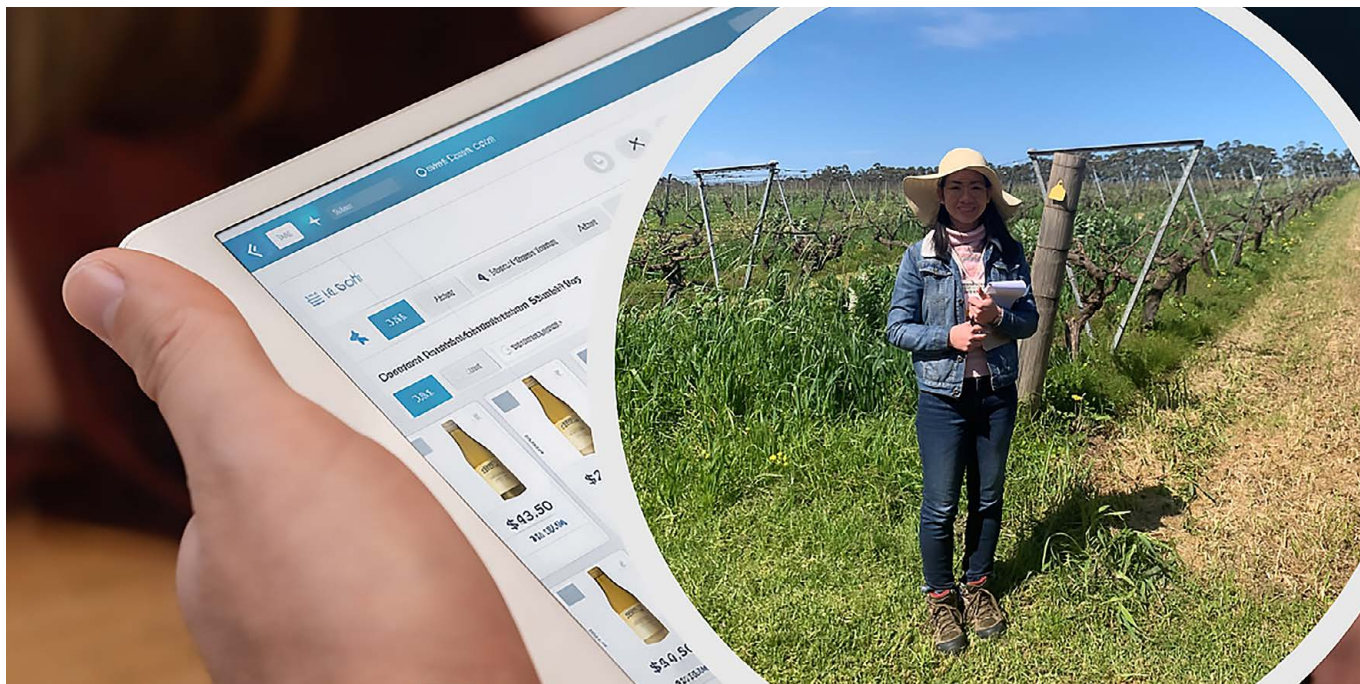
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Gen Y and Gen Z wine club members in Western Australia prioritise personalisation and relational engagement in Customer Relationship Management (CRM) programs.

Preferences for Customer Relationship Management Features among Gen Y and Gen Z wine consumers in Western Australia

Project team: Thi Kieu Oanh Nguyen¹ (project leader; Thikieuoanh.nguyen@research.uwa.edu.au), Associate Professor Michale Burton¹, Associate Professor James Fogarty¹, Associate Professor Amin Muger¹, Dr German Puga¹

Collaborating organisations: ¹UWA

This study investigates Gen Y and Gen Z consumers' preferences for Customer Relationship Management (CRM) features embedded in winery membership programs (wine clubs) within the Western Australian wine market. Grounded in consumer and random utility theories, a discrete choice experiment (DCE) was conducted with 434 wine consumers aged between 18 and 44 years to quantify trade-offs among six CRM attributes: communication channel, personalisation, membership benefits, delivery schedule, shipment quantity, and discount level. Mixed logit models were estimated to account for preference heterogeneity. Results show that personalisation, frequent delivery, and email communication significantly increased the utility of membership.

Brand attachment, age, and purchase frequency reduced the likelihood of not participating, whereas gender, education, and income had no significant effects. These findings indicate that personalisation and relational engagement drive young consumers' loyalty intentions in wine club settings. The results reinforce CRM's focus on leveraging trust and commitment to strengthen customer lifetime value and sustain long-term relationships.

Notes. The data used in this study were collected through an online survey administered via the Qualtrics platform. Ethical approval for this research involving human participants was granted by The University of Western Australia Human Research Ethics Committee (Approval No. 2024/ET000325).

This research is supported by Australian Government RTP Scholarship and UWA.



Effective use of Customer Relationship Management (CRM) tools enables wineries to connect customer interactions with data insights, supporting more targeted communication, personalised engagement and stronger loyalty among Gen Y and Gen Z wine customers.

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 Mazzarol¹ (project leader; tim.mazzarol@uwa.edu.au), Professor David Gilchrist¹, Professor Andrea Gaynor¹, Associate Professor Amin Muger¹, Dr Bruce Baskerville¹, Amber van Aurich¹, Peter Wells²

Collaborating organisations: ¹UWA; ²Co-operatives WA

The ongoing project conducts research on co-operatives and mutual enterprises (CMEs) in a variety of WA industries, including the agricultural sector. It aims to demonstrate the economic and social contributions CMEs make toward that State.

As a part of this project, the team published several case studies including *The Royal Automobile Club of Western Australia – A Driving Force for a better WA, 1905-2020*. This case is an update on Baskerville's 2022 book on the history of RAC WA. In addition, *York and District Co-operative Ltd. – Proudly serving the community since 1917*. This case demonstrates the contributions the Co-op York made to the region since 1917, including an in-depth

history of the Shire of York. A third case study was published, *Quairading Farmers' Co-operative Co. Ltd. – Cornerstone of our community*. This study examined the long history of the co-op, since 1916, and its contribution to the agricultural community over 108 years. The fourth case was *Galactic Co-operative Ltd: Working for a Scientific Solution since 2017*. This case explores the only worker co-operative in WA, and the impact of sustainability practices in the local and regional areas.

Lastly, this project published *From Orchards to Outlets: Mount Barker Co-operative Ltd. – Serving a changing region since 1918*. This case demonstrates the resilience of CMEs, as Mount Barker shifted from an agricultural packing and distributing enterprise toward a consumer co-operative, purchasing products and services for its members in the Mount Barker community.

The project has a forthcoming work to be published in 2026, *Capricorn Society Ltd. – Driving Members to Thrive since 1974*, examining the history of the automotive industry in Australia and New Zealand.

In addition, Tim Mazzarol published a third article on CME governance, providing beneficial tools and knowledge for CMEs in any industry. He also completed an analysis of Bank Australia, originally founded as the CSIRO Co-operative Credit Society in 1957.

The project also has a journal article in press with the *Journal of Co-operative Studies*.

Lastly, the project is in progress writing a book on CMEs for Routledge. This book takes an international scope and examines the theory underpinning CME creation and development. As a part of this, much of the cases are Australian agricultural co-operatives.

This research is supported by ARC, The Royal Automobile Club of WA Inc, Co-operatives WA, CBH Group, Capricorn Society Ltd, United Crate Co-operative Ltd, Mount Barker Ltd, and Wesfarmers Ltd.



Mount Barker estate orchards c.1930s. Credit: Mount Barker Co-operative 1939



Before bulk handling, Fremantle docks, 1916. Credit: SLWA

From Farm to Port: Logistics decision-making, infrastructure access and resilience in Western Australia's grain supply chain

Project team: Professor Doina Olaru¹
(project leader; doina.olaru@uwa.edu.au),
Garima¹, Associate Professor Brett Smith¹,
Hackett Professor Kadambot Siddique¹

Collaborating organisations: ¹UWA; ²GGA regional groups; ³DPIRD; ⁴GRDC

Western Australia's grain supply chain moves 20–27 million tonnes annually through a compressed 8–12 week harvest window, with over 90 per cent destined for export via five port zones. The 2025–26 season set a production record of 27.35 million tonnes, with Handlers receiving ~24.2 million tonnes. This intensifying production profile places unprecedented pressure on transport, receipt, and storage infrastructure. Yet existing research and decision support tools predominantly treat farmers as passive nodes in optimisation frameworks, overlooking how their decentralised logistics decisions interact with infrastructure constraints to shape system-level outcomes. This PhD research addresses this gap through a three-tiered investigation combining systematic literature review, mixed-methods empirical research, and agent-based computational modelling.

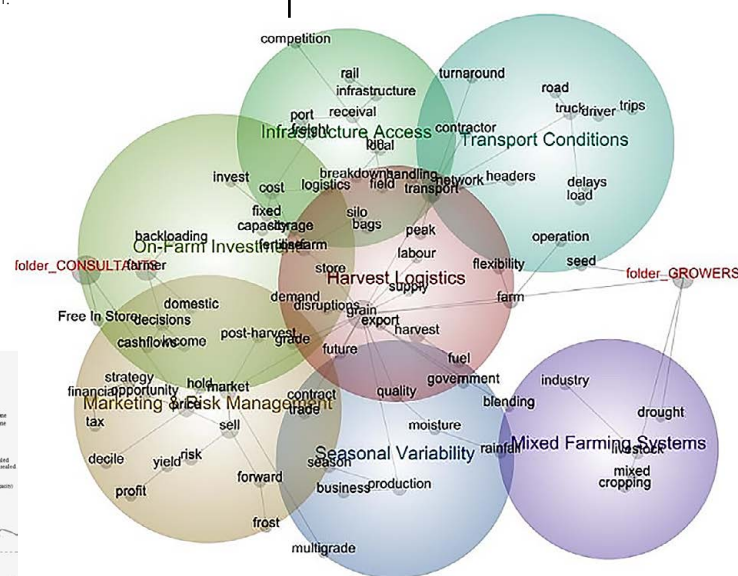
The research investigates how decentralised farm-level decisions interact with centralised logistics infrastructure to shape system-level outcomes. It aims to: 1) map the scholarly landscape and identify gaps in grain supply chain decision-making research; 2) document how WA farmers adapt harvest logistics strategies under infrastructure constraints and environmental uncertainty; and 3) translate qualitative behavioural findings into an agent-based simulation model for policy-relevant scenario analysis.

Two peer-reviewed journal articles were published from this research. The first, published in *Sustainability*, presented a systematic literature review of 85 papers and 19 systematic literature review (SLRs) on grain supply chain decision-making, identifying five key themes and a critical ‘farmer-resilience disconnect’ in which farmers are underrepresented in resilience research despite their foundational role. The second, published in *Agricultural Systems* reported a mixed-methods empirical study combining 48 surveys, 19 semi-structured interviews, and 242 media documents to investigate how WA grain producers adapt their storage, freight, and delivery strategies. This study introduced the concept of a three-layer Obligatory Passage Point structure (receiving silo, fortnight booking, port terminal) and documented seven key themes shaping harvest logistics through Actor-Network Theory and the ARA framework. Building on these empirical foundations, an agent-based model of the WA post-harvest grain supply chain has been developed and validated against historical season data. The model grounds its behavioural rules in the interview-derived findings through a qualitative-to-quantitative translation protocol and is currently being prepared for journal submission.

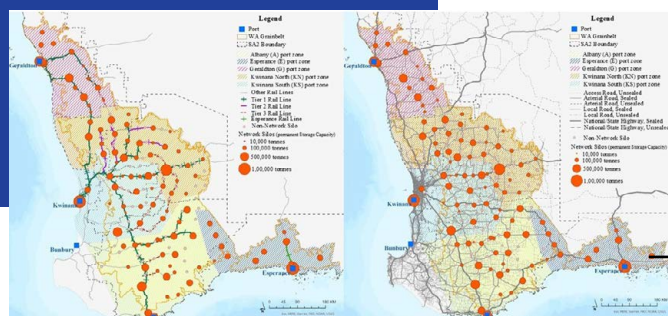
By repositioning farmers as active decision-makers rather than passive nodes in optimisation frameworks, this research provides the empirical and conceptual foundation for behaviourally realistic decision support in export-oriented grain systems. The systematic review established that farmers are critically underrepresented in supply chain resilience research, while the empirical study documented how scale, spatial location, and infrastructure access create differential vulnerability across the WA grainbelt. The validated agent-based model extends these insights by enabling infrastructure scenario analysis grounded in observed farmer behaviour – contributing evidence relevant to ongoing infrastructure planning and policy reform in Australia's grain logistics sector.

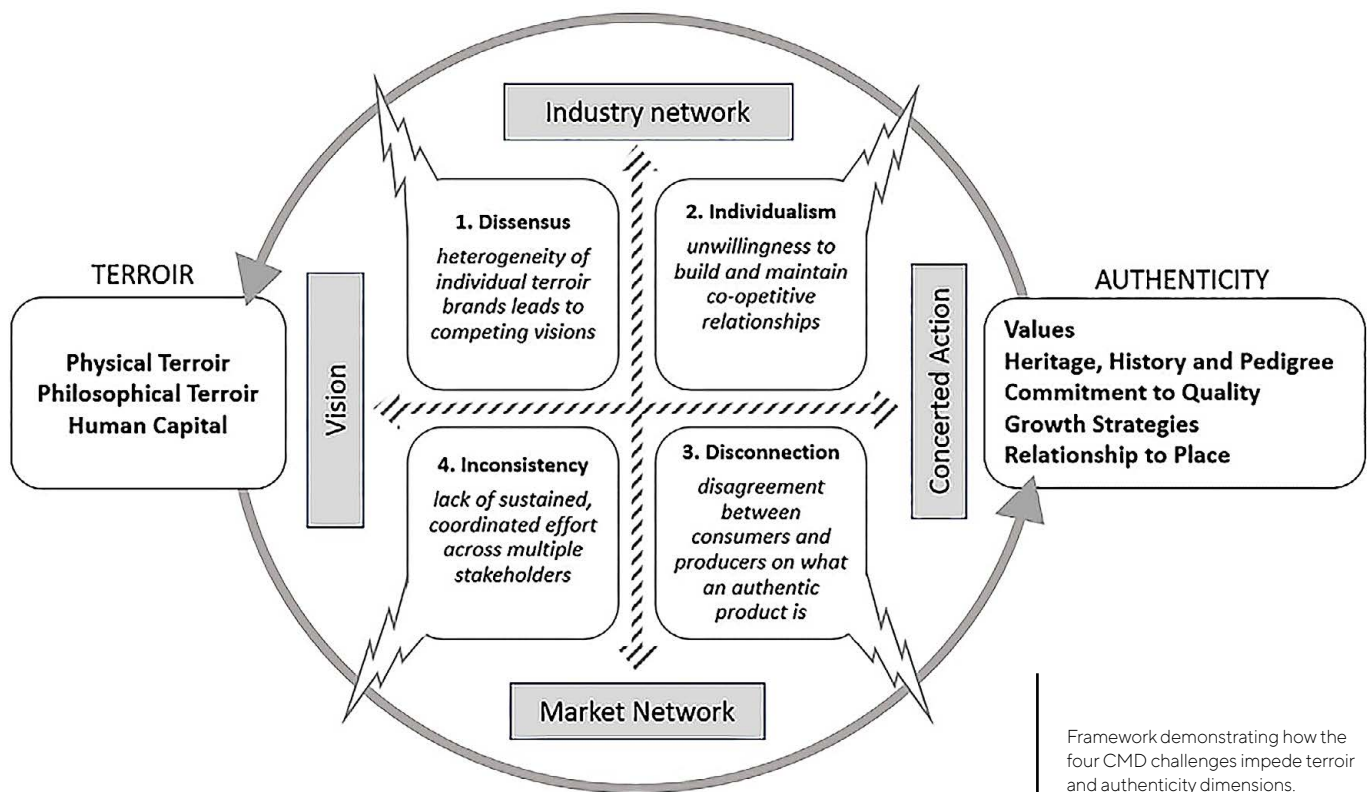
This research is supported by UWA International Fee Scholarship, GGA, Western Australia's Southwest Western Australia Hub's Extension and Adoption and Bursary funded by the Australian Government's Future Drought Fund.

The Leximancer concept map, shows the seven themes and their relational structure, and comes from the published *Agricultural Systems* paper.



Distribution and Permanent Storage Capacity
across the WA grainbelt, by port zones.





Blurred vision: Understanding barriers to initiating collaborative market driving

Project team: Associate Professor Daniel Schepis¹ (project leader; daniel.schepis@uwa.edu.au), Dr Kim Feddema², Dr Liudmila Tarabashkina¹, Professor Sharon Purchase¹

Collaborating organisations: ¹UWA; ²ECU

This paper aims to examine why many producers of origin-bound products struggle to collectively drive increases in market value, despite shared interests. The authors apply a collaborative market driving (CMD) lens to the early stages of collective efforts, to identify the key motivators, visioning processes and explore why CMD can fail to initiate.

The authors present a qualitative case study of the Western Australian monofloral honey industry. Data includes 64 producers' and distributors' online content and 30 interviews with stakeholders. Leximancer was used to map marketing communications, and participant narratives were thematically analysed using terroir and authenticity frameworks.

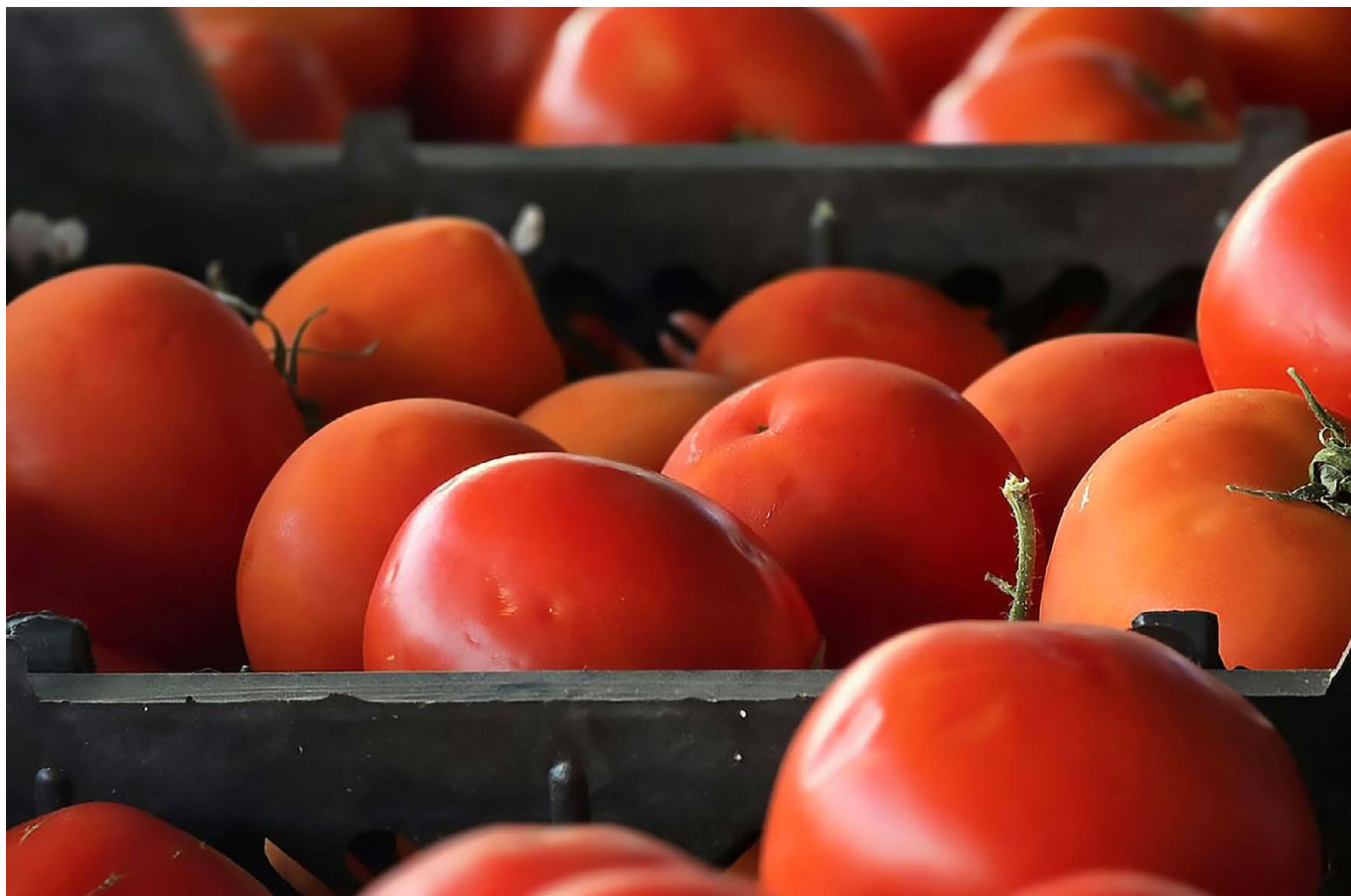
Stakeholders recognised the potential of terroir to support a shared, origin-based market vision. The authors found alignment between individual authenticity claims and collective terroir narratives. However, CMD efforts failed to initiate due to persistent barriers: financial instability, firm turnover, limited collaboration and conflicting priorities.

Findings are based on a single case where CMD has not succeeded; future work should explore how these barriers may be overcome in other contexts.

The authors outline four key barriers for initiating CMD: i) dissensus; ii) individualism; iii) disconnection and iv) inconsistency. The authors propose practical solutions to these barriers, which may motivate producers to initiate concerted action to pursue CMD more effectively, while opening up several future research opportunities.

This study uniquely explores CMD as a failed process, contributing a framework that combines terroir and authenticity to the development of collective market visions, while helping to explain the barrier which prevent tangible market driving action.

This research is supported by CRC for Honey Bee Products Grant: Honey Bee Products Marketing Program 4 Project Number 22B.



Tomatoes packed for transport.

Postharvest losses from temperature during transit: Evidence from a million truckloads

Project team: Dr Sarah C. Whitnall¹ (project leader; sarah.whitnall@uwa.edu.au), Professor Timothy K.M. Beatty²

Collaborating organisations: ¹UWA; ²University of California Davis, USA

Around 13 per cent of the global food supply is lost along production and supply chains including postharvest losses. This study investigates the effects of weather and climate change on postharvest losses in agricultural supply chains, focusing on California's processing tomato industry. Using data from approximately 1.4 million truckloads of tomatoes, the team examined how temperature and traffic conditions during transportation influence product quality after harvest. By comparing tomatoes grown in the same fields and season but transported under different conditions, the study isolates the effects of environmental and logistical factors on postharvest outcomes.

The research found that exposure to high temperatures during transportation increases postharvest losses, with the greatest impacts occurring when hot conditions coincide with heavy traffic and slower travel speeds. Longer transportation times were also associated with increased product damage. Although adverse temperature and traffic conditions could double the average rate of damaged produce, the overall economic consequences for growers were relatively modest. This reflects the short transport durations involved, the limited influence of quality losses on final prices, and the practical constraints surrounding adaptation measures such as refrigerated transport or expanded processing capacity.

Climate projections indicate that future warming is likely to result in only a small increase in postharvest losses for this industry by the end of the century.

Nevertheless, the study highlights the importance of considering supply-chain impacts alongside on-farm production losses when assessing the effects of climate change on agriculture. The findings suggest that growers located further from processing facilities may face greater risks under warming conditions and that adaptation strategies may need to extend beyond crop production to include investments in transport, logistics, and processing infrastructure. More broadly, the research contributes to a growing body of work examining how climate change affects agricultural systems after products leave the farm gate.

This research is supported by the Agriculture and Food Research Initiative grant no. 2023-67023-40081 from the USA Department of Agriculture's National Institute of Food and Agriculture.

Assessment of factors influencing farmers' adoption of flood-tolerant rice varieties in Nepal

Project team: Associate Professor Yoko Saito² (project leader; saitoy@agr.hokudai.ac.jp), Rin Akitaya², Associate Professor Ram Pandit¹

Collaborating organisations: ¹UWA; ²Hokkaido University, Japan

The impact of climate change has become serious, and the agricultural sector is especially vulnerable. Adopting stress-tolerant varieties is one of the adaptive strategies, but the adoption of such varieties remains low. Varietal maintenance research, which adds biotic or abiotic stress tolerance to existing varieties, can reduce the climate vulnerability for farmers.

In this context, factors that could accelerate the adoption of submergence-tolerant rice (SUB1) varieties are assessed in Chitwan district of Nepal, where rice crops are

increasingly exposed to submergence conditions due to flooding. Household surveys were conducted in October 2019 and 2022 in two regions – Madi and Bharatpur – of the district. Data from 268 households were analysed using a pooled binomial logit model, which can efficiently identify farmers' adoption decisions.

Results reveal that peer learning and an expanding farmer network accelerate the adoption rate. Farmers' adoption decision also depends on their access to inputs, particularly pesticides. Policies to promote climate resilience should also focus on awareness of SUB1 variety, as well as reducing the constraints faced by resource-poor farmers. Understanding farmers' decisions in local contexts can promote adoption of stress-tolerant varieties.



Farmer working in a flooded rice field in Nepal.

This research is supported by The Japan Society for the Promotion of Science Grants-in-Aid for Scientific Research KAKENH Grant Numbers: 20K01601 and 20K06250.

Challenges and changes in Australia's grain production and supply chains

Project team: Emeritus Professor Ross Kingwell^{1,2} (project leader; ross.kingwell@dpird.wa.gov.au)

Collaborating organisations: ¹UWA; ²DPIRD

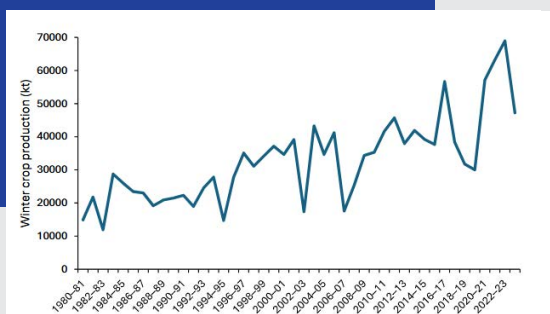
This paper examines structural, spatial, and temporal changes in Australia's grains industry and their implications for national grain supply chains. It highlights significant shifts in agricultural production patterns over recent decades, including a major expansion of winter cropping, which now

dominates Australian agricultural land use. This growth in grain production has increased both the volume and diversity of outputs, placing greater pressure on supply chain systems to remain efficient, cost-effective, and reliable.

Given the importance of grain supply chains to domestic food prices, export earnings, and farm profitability, the note emphasises the need for strategic investment, technological innovation, and policy reform to support system efficiency and resilience.

While there are strong opportunities for improvement, progress is constrained by limited state government fiscal capacity, complex stakeholder environments, and risk-averse policymaking processes. Overall, the paper argues that coordinated industry and government action is essential to ensure long-term competitiveness and economic benefit for Australia's grains sector.

This article was drawn on research supported by the AEGIC and GRDC AEG2304- 003RTX.



Australia's winter crop production since 1980.
Source: ABARES Australian Commodity Statistics 2024

Wheat crop at UWA Farm Ridgefield Credit: Peter Maloney.





Winthrop Hall at UWA Crawley Campus.



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 December 2025 newsletter.



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

The uwa.edu.au/ioa 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 2025, IOA's social media audience increased significantly. The IOA LinkedIn was once again the fastest growing audience, growing by 1,362 new followers to a total of 8,622. Six event videos published to YouTube in 2025 amassed more than 1,355 views. The @IOA_UWA X gained 102 more followers to end the year with an audience of 3,591.

Visitors to IOA

Engagement with universities, industry, government, and the broader agricultural community remains central to IOA's mission. These interactions strengthen research collaborations, support knowledge exchange, and connect our work to real-world impact.

Throughout 2025, IOA welcomed a diverse range of visitors, guest speakers, and collaborators to UWA, contributing to a vibrant program of events, lectures, and industry engagement activities.

Public lectures remained a cornerstone of IOA's engagement activities in 2025, providing a platform for leading experts to share insights, spark discussion, and connect research with industry and community audiences. In February, IOA hosted Professor P.O. Nameer from Kerala Agricultural University for a week-long visit focused on strengthening international research collaboration. IOA also welcomed Associate Professor Sruthi Narayanan from Clemson University in June. During her sabbatical visit, she delivered a public lecture on climate-resilient agriculture, presenting cutting-edge research on crop adaptation and sustainable farming systems.



Photos (clockwise from top left):

Associate Professor Sruthi Narayanan from Clemson University presents her lecture on climate-resilient agriculture.

2025 Industry Forum participants with Chief Scientist of WA Professor Sharath Sriram, IOA Director Hackett Professor Kadambot Siddique and IAB Chair Terry Enright.

CSBP leadership team members tour UWA's glasshouse facilities, where they gained insight into sustainable crop production research.

Professor Sukkarieh with Associate Professor Andrew Guzzoni and Dr Monte Massarelli at CEI:AgER at Shenton Park Field Station.

Postgraduate Showcase PhD student presenters with His Excellency the Honourable Chris Dawson AC APM, Governor of Western Australia, UWA Vice Chancellor Professor Amit Chakma, Professor Kadambot Siddique, Professor Tim Sercombe, Professor Anu Rammohan and Diana Boykett.

The Honourable Minister for Agriculture, Jackie Jarvis MLC with IOA team at Dowerin Machinery Field Days 2025.

In July, Dr Gustave Gintzburger delivered a well-attended lecture exploring arid rangeland systems, drawing connections between North African pastoral landscapes and Western Australian rangelands. International collaboration was further strengthened through visits such as that of Professor Ida Ayu Astarini from Udayana University, who presented on sustainable rice production systems in Bali, and through ongoing partnerships supporting student exchange and joint research initiatives.

A key highlight was the 19th annual Industry Forum, held in August at The University Club of Western Australia, which focused on the future of Australia's agricultural research, development, and extension landscape. Winthrop Professor Fiona Wood challenged attendees calling for greater courage, risk-taking, and impact in shaping the future of agricultural innovation. Dr Beth Woods complemented this perspective with a systems approach, advocating for a shift towards improving diets, supporting local food systems, and fostering stronger cross-sector collaboration. Together with industry voices, the Forum reinforced the need for a more connected, forward-looking RD&E ecosystem.

Complementing these discussions, the 2025 Hector and Andrew Stewart Memorial Lecture was delivered by Professor Salah Sukkarieh, who explored the integration of physical and digital agriculture. During his visit, Professor Sukkarieh also engaged with the Centre for Engineering Innovation: Agriculture & Ecological Restoration.

Beyond campus, IOA maintained a strong presence at major industry events, including the Dowerin Machinery Field Days and the GRDC Grains Research Update. Industry engagement was further strengthened through visits such as the CSBP leadership team's tour of UWA's glasshouse facilities, where they explored ongoing research in nutrient use efficiency and sustainable crop production.

Together, these visits and events reflect IOA's ongoing role as a hub for collaboration, innovation, and knowledge exchange, connecting research, industry, and community to address the challenges and opportunities facing agriculture today.

Visitors to IOA

Name of visitor	Visitor's organisation and country	Host details	Dates of visit
Director and Vice-Chancellor, Prof Manoj Dhar Prof Ajay Dhar, Associate Director (Academic) Ms. Aarti Katoch, Manager, International Academic Partnerships	AcSIR, India	IOA, H/Prof Kadambot Siddique	10 March
Alex Lloyd, CEO Dr Mary Carr, Head of Collaborations, Research & Impact	CRC SAAFE	IOA, H/Prof Kadambot Siddique	24 March
Prof P.O Nameer	Kerala Agricultural University, India	IOA	3-10 May 2025
Clement Chatard	VetAgro Sup, France	IOA	May-Aug 2025
Dr Sruthi Narayanan	Clemson University, USA	IOA	15-29 June 2025
Atiqa Ishtiaq	The Government College University Faisalabad	IOA	1 July – 29 Dec 2025
Dr Gustave Gintzburger	Samarkand State University, Uzbekistan	IOA	16 July 2025
Dr Baethadj Hamdi-Aissa	University of Auargla, Algeria	IOA	25 July 2025
Prof Xingguo Zhang & Prof. Guangwei Li	Henan Agricultural University, China	Dr Sheng Chen	6 Aug 2025
Prof Pei Xu, Dr. Min Xu & Dr. Yang Su	China Jiliang University, China	Dr Sheng Chen	18 Sept 2025
Dr Raymond Cowley & Ms Emily Blyton	Corteva Agriscience, Australia	Dr Sheng Chen	9 Oct 2025
Prof Ir. Ida Ayu Astarini	Udayana University, Bali, Indonesia	H/Prof Kadambot Siddique	28 Oct 2025
I Gusti Agung Ayu Rai Asmiwyati	Udayana University, Bali, Indonesia	H/Prof Kadambot Siddique	29 Sep 2025
Dr Anca Awal Sembada	Bandung Institute of Technology, Indonesia	H/Prof Kadambot Siddique	3 Nov 2025



SNAGS students with South Regional TAFE Native Forest Transition Manager Diana Fisher Hackett Professor Kadambot Siddique, Dr Kelsey Pool and Professor Megan Ryan.

UWA research on show at GRDC Grains Research Update

UWA's innovative research, automation, and collaboration took centre stage at 2025 GRDC Grains Research Update.

UWA researchers Karen Nelson and Dr Aneeta Pradhan kicked off with strong presentations in the "New Researchers" session on Monday. Their joint talk '*Good Timing: Marker-assisted backcrossing rapidly moves a new flowering gene into commercial narrow-leaved lupins*' captivated the audience, highlighting their latest research contributions to the industry.

The Centre for Engineering Innovation: Agriculture & Ecological Restoration Director Associate Professor Andrew Guzzoni and Dr Wesley Moss took part in a panel discussion on grain automation. They explored the growing role of autonomy in agriculture and the need for developing capabilities and awareness in tertiary education.

IOA's information stall was a hub of activity, with Communications Officer Ana Mendigutxia Balil, Hackett Professor Kadambot Siddique, and researchers Agyeya Pratap and James O'Connor discussing UWA's contributions to agricultural research and innovation.

Hackett Professor Kadambot Siddique, PhD students Agyeya Pratap, Dr Asad Prodhan from DPIRD and IOA IAB member Dr Hayley Norman from CSIRO.



Ag careers night opens doors for future industry leaders

Students from across Western Australia explored career opportunities in agriculture at the annual Agricultural Careers Night at the Royal Agricultural Society Showgrounds in April.

Organised by the Ag Institute of Australia (AIA) WA Division, the event featured a speed-networking format with 10–15 five-minute 'rounds' followed by informal discussions over pizza, offering students a chance to connect with industry experts.

Representatives from top organisations, including ANZ, CBH Group, Rabobank, CSBP were on hand to discuss various career paths and opportunities within the agricultural sector. The IOA was represented by Director Hackett Professor Kadambot Siddique, Associate Director Professor Wallace Cowling and Emerita Professor Lynette Abbott, who spoke with students about pathways into postgraduate research.

"The AIA WA Division has proudly organised this event every year, and we are thrilled to see it continue to grow as a key opportunity for our student cohort to engage with potential employers," AIA WA Division secretary Natalie Moore said.

Many students stayed after the event, keen to continue discussions on the future of agriculture, including the growing role of technology and sustainability in the sector.

Travelling Fellowship expanding global agricultural research training horizons

The 21st Mike Carroll Travelling Fellowship presentation evening brought together students, researchers, and the Carroll family to celebrate the impact of global research training experiences.

Established in memory of Dr Mike Carroll, former Director General of the WA Department of Agriculture, the Fellowship has supported 32 postgraduate students since 2003, enabling them to engage with leading researchers and institutions worldwide.

This year, PhD candidates Agyeya Pratap and Ruby Wiese shared insights from their Fellowship-supported travels. Agyeya, whose research focuses on heat tolerance in bread wheat, visited the Umeå Plant Science Centre in Sweden for a lab visit and attended the Tropentag 2024 conference in Vienna, where he presented a poster on his research. Meanwhile, Ruby travelled to the United States, attending the International Plant Phenotyping Symposium in Nebraska and meeting with pasture researchers in Oregon to advance her work on harvesting subterranean clover seed.

The event was attended by members of the Carroll family, including Helen Carroll, her daughter Marie-Louise Carroll, and granddaughters Abbie and Coco Divola.

The IOA extends its gratitude to the donors of the Mike Carroll Travelling Fellowship bequest fund for their ongoing support. These opportunities continue to broaden students' global perspectives and enhance their research careers.



Invitees to the Mike Carroll Travelling Fellowship event, PhD candidates Agyeya Pratap and Ruby Wiese, alongside members of the Carroll family.



Associate Professor Sruthi Narayanan from Clemson University presents her lecture on climate-resilient agriculture.

Exploring climate-resilient agriculture in the Omics Era

As part of her two-week sabbatical to UWA, Associate Professor Dr Sruthi Narayanan from Clemson University delivered a public lecture on 18 June in the Alan Robson Agriculture Lecture Theatre.

Attended by more than 30 participants, her lecture provided a comprehensive overview of her team's eco-physiological research on crop resilience under abiotic stress. By integrating molecular physiology with production agronomy, her work seeks to develop agricultural systems that are both climate-resilient and economically viable.

Structured around two key themes, crop adaptation to climate change and sustainable cropping systems, the lecture first examined the identification of stress-tolerant traits, mechanisms, and genotypes. These findings support breeding programs targeting crops adapted to future environmental conditions.

The second half focused on improving agronomic practices to enhance water use efficiency, soil health, and stress tolerance. Together, these strategies aim to advance the productivity and environmental sustainability of agricultural systems.

During her visit, Associate Professor Narayanan toured the Canola projects at the Shenton Park Field Station alongside Professor Wallace Cowling and Dr Shen Chen. She engaged with several researchers including IOA Director and strengthened collaborative opportunities in plant physiology, breeding, and sustainable agriculture.

Exploring tribes, territories, and ecological wisdom from Libya to Western Australian rangelands

In July, the Alan Robson Lecture Theatre reached full capacity as more than 50 attendees gathered to hear Dr Gustave Gintzburger share insights from over five decades of research in arid rangeland ecosystems.

Drawing on his recent book *The Rangelands of Libya* (CABI, 2025), co-authored with Dr Slim Saïdi, Dr Gintzburger delivered a public lecture titled '*Tribes, Territories, and the Ecology of Survival: Insights from Libyan Landscapes and Their Relevance to Australian Rangelands*'.

He explored the ecological, cultural, and historical dimensions of Libya's pastoral landscapes, touching on tribal land use, traditional water systems, and the resilience of nomadic grazing practices.

Dr Gintzburger also reflected on the relevance of these systems to Western Australia's rangelands, particularly in the face of climate change and the growing need for sustainable land management strategies.

The lecture concluded with an engaging discussion, as Dr Gintzburger responded to audience questions and shared further reflections on his experiences working across North Africa and Australia.



Dr Gustave Gintzburger sharing decades of research into arid rangeland ecosystems.



PhD student Ruby Wiese presenting at the 2025 Postgraduate Showcase.

Postgraduate Showcase celebrates the interdisciplinary nature of agricultural sciences

The UWA Institute of Agriculture's 19th annual Postgraduate Showcase drew an enthusiastic crowd to the Bayliss Lecture Theatre in May, where students, industry professionals, and government representatives came together to celebrate the future of agricultural research.

The event was officially opened by His Excellency the Honourable Chris Dawson AC APM, Governor of Western Australia, whose thoughtful remarks highlighted his strong connection to and understanding of the state's agricultural landscape. UWA Vice-Chancellor Professor Amit Chakma also attended, reaffirming the UWA's ongoing commitment to agricultural excellence.

Six exceptional PhD students presented insights from their research, covering diverse topics from engineering to agribusiness including sustainable seed harvesting, climate resilience, and supply chain economics.

Chaired by Professor Tim Sercombe, Dean and Head of UWA's School of Engineering, the first session opened with Ruby Wiese, who presented her work

on 'Evaluating sustainable subterranean clover seed harvesting methods', offering promising insights for pasture systems. George Mercer followed with his research on 'Transforming biosolids into stable soil carbon', demonstrating the environmental potential of organic waste reuse. Aggyeya Pratap concluded the first session with a presentation on heat stress tolerance in wheat, exploring physiological and proteomic changes that could boost crop resilience to heat stress.

The second session, chaired by Professor Anu Rammohan, Director of International Relations at the UWA Business School, focused on economics and global systems. Garima explored grain logistics and supply chain resilience in Western Australia, while Emanuel Gomez presented on 'Investigating the economics underpinning traceability investment decisions of Australian grain sustainability credentials', helping bridge research with industry realities.

The final presentation was delivered online by Jelena Um, a joint PhD student between Nagoya University and UWA, who captivated the audience with her research on 'Effects of phytosterol profiles in genetically modified (GM) plants on post-embryonic development of phytophagous insects'.

"This showcase is about recognising emerging researchers who are already making real contributions to agricultural science," IOA Director Professor Kadambot Siddique said.

"It's inspiring to see such passion, clarity, and purpose in their work," he said.

"The strong turnout and level of engagement reflect just how relevant and impactful our research community continues to be."



Postgraduate Showcase PhD student presenters during the event.

We do research well, but is it enough?

A bold call rung out at the 2025 Industry Forum With a single, striking question, Winthrop Professor Fiona Wood set the tone for The UWA Institute of Agriculture's 19th annual Industry Forum on 6 August.

The proceedings were formally introduced by IOA Director Professor Kadambot Siddique, who highlighted the Forum's enduring role over the past 19 years as a platform for rigorous debate on the most pressing issues in agriculture.

In 2025, attention turned to a particularly urgent and contested matter: the future funding landscape for Australia's agricultural research, development, and extension (R, D & E) over the coming two decades.

Serving as MC, Farm Management Consultant and IOA Industry Advisory Board member Carly Veitch welcomed attendees and set the stage for what became a forward-looking discussion introducing Winthrop Professor Fiona Wood AO, FRCS, FRACS.

"Do we have an appetite to do better?" asked Professor Wood, challenging the room to reflect beyond success metrics.

As member of the Strategic Examination of Research and Development panel, her address traced the evolution of federal funding in agricultural innovation and urged attendees to embrace risk, integrity, and urgency. "The bigger risk is that we don't take a risk at all," she said.

The momentum for transformation continued with keynote speaker Dr Beth Woods OAM, who shared insights drawn from across Australia's Rural Research and Development Corporations.

"If our focus question was how we improve diets for local Australians, we'd design our system differently," she remarked, urging a shift away from narrow productivity goals.

Professor Fiona Wood

Woods advocated for a whole-of-system approach, one that prioritises local food systems, reduces waste, and opens the door to new partnerships across retail, philanthropy, and beyond.

"We need to start investing now... rather than playing catch-up later."

Industry perspectives were sharply delivered by Tress Walmsley, CEO of InterGrain. Drawing on real-world examples, she emphasised the need for a connected, collaborative innovation ecosystem.

"Stop accepting the status quo... lean in and participate in the conversation on how we can remodel the RD&E ecosystem," she said.

Representing the farming community, Paul McKenzie, farmer, company director and agriculture consultant, highlighted the

need for more transparent governance and stronger farmer representation in levies investment. His message was clear: empower farmers to lead, not just contribute.

The Forum concluded with a dynamic panel discussion facilitated by Terry Hill. The session brought together diverse perspectives from presenters and participants, sparking lively Q&A exchanges and thoughtful debate.

Supported by CSBP and the Farmers Ltd Jubilee of Agriculture Science Fellowship, the 2025 Industry Forum reaffirmed the ongoing commitment of IOA to work with the agricultural community to innovation, dialogue, and sustainable investment in Australia's agricultural future.

Winthrop Professor Fiona Wood delivering her keynote address at the 2025 Industry Forum.



Farmer Paul McKenzie addresses attendees in the University Club of WA main auditorium.



Andrew Robson and Senior Deputy Vice-Chancellor Professor Tim Colmer pictured beside the portrait of the late Professor Alan Robson.

A lasting tribute to late Professor Alan Robson

In September, colleagues, friends, and members of the UWA community gathered in the Alan Robson Agriculture Lecture Theatre to unveil a portrait honouring the late Professor Alan Robson.

The function was led by IOA Director Professor Kadambot Siddique, who reflected on Alan's remarkable career as a teacher, mentor, and leader. He highlighted Alan's lasting contributions to agriculture, higher education, and community service, and the profound influence he had on generations of students and colleagues.

Professor Siddique noted that his portrait now stands as a symbol of gratitude and remembrance, complementing other tributes across campus that recognise Alan's enduring legacy.

The unveiling was performed by Andrew Robson and Senior Deputy Vice-Chancellor Professor Tim Colmer. It was an opportunity for the UWA community to come together, to remember a man who shaped so much of what UWA is today, and to reaffirm a commitment to carrying forward his vision for the future.

Strengthening research connections between UWA and Kerala Agricultural University

In February, The UWA Institute of Agriculture warmly welcomed Professor P.O. Nameer, Dean of the College of Climate Change and Environmental Sciences at Kerala Agricultural University.

Professor Nameer's week-long visit focused on research collaboration and knowledge exchange. With more than 30 years' experience studying biodiversity in India's Western Ghats, Professor Nameer interacted with UWA researchers, the Head of the School of Agriculture and Environment, representatives from the Global Engagement Office, and Professor Andrew Page, Pro Vice Chancellor (Research).

Together, they discussed opportunities to strengthen joint efforts in biodiversity monitoring, climate change adaptation, and sustainable agriculture.

A highlight of Professor Nameer's visit was his insightful lecture on the Kerala Bird Atlas and the Role of Citizen Science in Biodiversity Monitoring, held at the Alan Robson Agriculture Lecture Theatre.

He showcased how more than 1,000 trained volunteers contributed to India's largest bird mapping project, documenting 380 species across 3,500 square kilometres.

The lecture also reflected on more than 15-years of partnership between Kerala Agricultural University and IOA, including the exchange PhD students, which has enriched research on biodiversity and sustainable agriculture in both countries.

Professor P.O. Nameer presents his lecture, sharing insights from India's largest bird mapping project.





SNAG students visit the at IOA stall at Dowerin Machinery Field Days 2025.

Growing research and connections at Dowerin Machinery Field Days 2025

The UWA Institute of Agriculture proudly marked its 19th consecutive year at the flagship 2025 Dowerin Machinery Field Days, held on 27–28 August.

The event once again proved to be an outstanding platform to connect with farmers, researchers, industry partners and policymakers, while sharing our research with the wider agricultural community.

Housed within the DPIRD shed, the IOA stall highlighted the latest agricultural research and key projects from UWA Farm Ridgefield.

Visitors had the opportunity to explore innovative approaches to sustainable farming and discover how UWA research is contributing to practical, on-ground solutions for the agricultural sector.

A highlight of the first day was welcoming the Honourable Minister for Agriculture, Jackie Jarvis MLC.

IOA Director Professor Kadambot Siddique and IOA Business Manager Diana Boykett shared insights into ongoing projects and the pioneering work being undertaken at UWA Farm Ridgefield.

The stall also enjoyed the visit from SNAGS Dowerin Agricultural Camp 2025 students.

The stall was managed by IOA Communications Officer Ana Mendigutxia Balil, PhD students Garima and Pragya Poudel and agriculture sciences undergraduate student Feba Joshy, and who engaged with visitors and highlighted the breadth of IOA's research activities.

Farming in two worlds: Professor Sukkarieh shows the future of digital agriculture

The 31st Hector and Andrew Stewart Memorial Lecture offered a glimpse into the present and future of agriculture, where digital innovation meets traditional farming.

On 25 September 2025, Dr Salah Sukkarieh, Professor of Robotics and Intelligent Systems at the University of Sydney, delivered the Hector and Andrew Stewart Memorial Lecture titled “Farming in Two Worlds: Integrating Physical and Digital Agriculture” at Wilsmore Lecture Theatre.

More than 50 attendees, including farmers, industry leaders, academics, students, and members of the Stewart family, joined the event.

“The farming industry and robotics are revolutionising each other. The innovations born from agriculture are redefining the future of technology,” Professor Sukkarieh said.

Drawing on more than 20 years of experience in agricultural robotics, Professor Sukkarieh explored how combining real-world farming with advanced digital technologies can transform agricultural systems.

He highlighted the use of Digital Twins, AI, IoT networks, and robotics to improve soil and water management, crop and livestock monitoring, and farm labour efficiency.

“There’s no conflict — the farming industry is shaping robotics, and robotics is shaping farming,” he said.

“What we learn from agriculture directly influences how we develop technology.”

Case studies illustrated how these innovations are helping farms become more adaptive, sustainable, and resilient.

As part of his visit to UWA, Professor Sukkarieh also engaged with UWA’s agricultural engineering community.

He met with Associate Professor Andrew Guzzomi and the CEI:AgER team to tour around Shenton Park Field Station and discuss collaborative opportunities in precision agriculture and digital farming.

Professor Salah Sukkarieh presents on integrating physical and digital agriculture.



Professor Sukkarieh with the Stewart family and UWA staff and academics.



Exploring sustainable rice production in Bali

The UWA Institute of Agriculture hosted a lecture by Professor Ida Ayu Astarini on sustainable rice production using local land races in October.

The lecture, which explored sustainable rice production using local land races by applying a case study of the Subak system in Bali, took place at the Alan Robson Agriculture Lecture Theatre.

Professor Astarini shared insights into the Subak system, a traditional Balinese irrigation and social organisation recognised by UNESCO.

This system integrates centuries of agricultural knowledge, local rice varieties, and cultural practices, coordinating water sharing, planting schedules, and ceremonies dedicated to Dewi Sri, the rice goddess. Beyond rice cultivation, the Subak exemplifies *Tri Hita Karana*, the Balinese principle of harmony between people, nature, and the divine, offering a model for sustainable rice production under changing climate conditions in the region.

Professor Astarini is a distinguished researcher in plant biotechnology at Udayana University, Bali, Indonesia and holds a Masters and PhD from UWA. Her expertise in crop improvement, sustainability, and biodiversity conservation has driven impactful international collaborations and numerous awards, reflecting her leadership in applying scientific innovation to environmental and agricultural challenges.

This lecture was part of Professor Astarini's visit to UWA, where she also engaged with faculty members from IOA to discuss research collaboration and sustainable agriculture initiatives.



Professor Ida Ayu Astarini delivers lecture on sustainable rice production and Bali's Subak system.



CSBP leadership team members tour UWA's glasshouse facilities, where they gained insight into sustainable crop production research.

CSBP leadership team tours UWA's glasshouse experiments

On 15 September, more than 40 members of CSBP senior management team gathered at UWA for their leadership meeting.

During their visit, they took the opportunity to tour the UWA glasshouses, where The UWA Institute of Agriculture hosted them for an inside look at the innovative research driving sustainable crop production at the University.

The visit began with the UWA Plant Growth Facility Manager Rob Creasy, who gave an overview of the growing facilities and introduced the newly opened Australian Plan Phenomics Network UWA Node facilities.

Dr Sneha Reddy and Dr Lukasz Kotula presented their GRDC funded work on improving nitrogen-use efficiency in canola, aiming to identify varieties that make better use of nutrients and reduce environmental losses.

PhD student Shuyan Li shared her research on enhancing phosphorus-use efficiency in wheat by lowering seed phosphorus and phytate levels to improve grain nutrition and sustainability.

Fellow PhD candidate Manika Debnath discussed her research comparing slow-release nitrogen fertilisers with conventional urea in wheat and canola, exploring pathways to more efficient nutrient delivery and lower environmental impact.

The group remained actively engaged throughout the visit, asking questions, sharing ideas, and exploring the science behind sustainable farming.

The tour highlighted the importance of the research being carried out at UWA and the value of collaboration between industry and academia in shaping the future of agriculture.



Best Practice Farming Systems Project: 2025 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

A key highlight of the Best Practice Farming Systems Project's outreach and engagement program in 2025 was a visit from ABC Landline. Presenter Halina Baczowski visited UWA Farm Ridgefield in August to film the MLA funded 'Shade and Shelter' project, a collaboration between UWA, Murdoch University, CSIRO and NSW DPI.

UWA's Professor Shane Maloney and Dr Kelsey Pool, together with IAB member Dr Hayley Norman, CSIRO, and Murdoch University collaborators Associate Professor Serina Hancock and PhD candidate Georgia Welsh, were interviewed and shared insights into the impact shade and shelter has on sheep reproduction and welfare. The segment aired on 31 August 2025.

The team engaged with farmers, the broader agricultural industry, the scientific community and the general public through several key events in 2025, including the GRDC Grains Research Updates, Perth in February, and the Dowerin Field Days in late August. At each event, information about UWA Farm Ridgefield and the BPFS Project was shared through flyers, posters, and discussions with attendees.

The BPFS Project's strong online presence also enabled engagement with audiences around the world. By the end of 2025, more than 2,600 people were following the BPFS Project Facebook Page.

Throughout the year, five newsletter articles and two media releases highlighting research activities at Ridgefield were published.

Photos (from top left to bottom right):

Domestic and international agricultural science students toured UWA Farm Ridgefield and experienced real-world wheatbelt production systems firsthand.

Dr Kelsey Pool conducting experimental research on sheep fertility and thermal stress.

Master of Biotechnology students visited UWA Farm Ridgefield to research soil health and sustainable farming. Pictured left to right: Sanjida Fatima, Pavan Anil Kumar, Emeritus Professor Lynette Abott and Aleena Saju.

Year 9 students from John Calvin Christian College gain hands-on experience in sustainable farming and land at UWA Farm Ridgefield.



Research, education and training

On-farm education and training remain strategic priorities of the BPFS Project, supporting learning opportunities from high school through to Bachelor, Master's and doctoral levels.

In August 2025, French exchange student Clement Chatard visited Ridgefield to assist the team investigating methane emissions reduction in livestock during lambing. Farm tours for students from John Calvin Christian College, WA College of Agriculture, Narrogin and Byford Secondary School were also conducted throughout the year.

More than 70 UWA undergraduate and postgraduate students attended study

excursions to Ridgefield or visited for research purposes. This included students enrolled in Pasture and Livestock Systems unit, Food Fibre and Fuel Security unit, and Clean Green and Ethical Animal Production unit.

The Massive Open Online Course (MOOC) *Discover Best Practice Farming for a Sustainable 2050* continued to attract new enrolments, reaching more than 45,000 unique enrolments since its launch in 2017. The free course provides an overview of major issues in sustainable agriculture, illustrated through the four key enterprises of the BPFS Project: livestock, cropping, sustainability and a vibrant community.

Almost 20 research projects were underway on UWA Farm Ridgefield throughout 2025. The projects covered a diverse range of topics including improving

lamb survival, developing optimal feeding strategies, improving sheep temperament and cognitive function, reducing methane emissions, improving soil health, understanding nitrogen cycling in Australian cropping systems and advancing pasture breeding.

Together, these activities demonstrate the BPFS Project's ongoing commitment to delivering impactful research, fostering industry engagement, and building the next generation of agricultural professionals. Through its integrated approach to research, education, extension and collaboration, UWA Farm Ridgefield continues to play a leading role in developing innovative and sustainable farming systems that support the productivity, resilience and long-term prosperity of Australian agriculture.



Media releases 2025

Date	Title
11 February	Consumer choices shaping the future of climate-impacted produce
13 March	UWA technology set to transform agricultural monitoring
19 March	New test measures antibacterial properties of honey
4 May	Accolades grow for world-leading agricultural scientist
12 May	Wheat heat-tolerance insights for climate resilient varieties
14 May	Wheat study addresses growing global zinc deficiency
26 May	New research links global warming to rising crop failure risks
3 June	Study finds degradable film mulching increase soil carbon storage
17 June	Soil carbon holds the key to protecting global crop yields from climate change
26 June	Lifelong dedication to agriculture recognised with honorary doctorate in India
2 July	New plant phenotyping facility to help WA farming grow
8 July	Farming strategy tackles food security, climate change and soil degradation
14 July	The UWA Institute of Agriculture Releases Annual Research Report 2024
23 July	First-ever mapping of soil pathogens offers hope for Ethiopian farmers
1 September	Unlocking the keys to improving nitrogen use efficiency in wheat
11 September	Smarter fertiliser use through outsourced services to support wheat farmers
18 September	Eco-tech spin-out to restore native biodiversity to degraded land
1 October	Quairading farmers' co-op driving community strength over century
9 October	Diverse forestry to build resilience for a warming world
18 November	Farm logistics under pressure from shifting harvest constraints
19 November	UWA researchers at the top of their fields
21 November	Global study unveils blueprint to turn drylands into carbon sinks
4 December	Impact of rising heat on California tomato supply offers insight for Australia

Awards and industry recognition

Name	Award
H/Prof Kadambot Siddique	Adjunct Professor in Plant Physiology – ICAR-Indian Agricultural Research Institute
Boyu Zheng	Mike Carroll Travelling Fellowship
Miguel Vaz Pereira	Mike Carroll Travelling Fellowship
H/Professor Kadambot Siddique	2024 Highly Ranked Scholar in All Fields of Scholarly Endeavour, Scholar GPS
H/Professor Kadambot Siddique	2025 Research.com Plant Science and Agronomy in Australia Leader Award
H/Professor Kadambot Siddique	2024 Crawford Fund Medal, in recognition of considerable and continued contribution to international agricultural research through the Crawford Fund's programs and related activities.
H/Professor Kadambot Siddique	Doctorate (Honoris Causa), Kerela Agricultural University
H/Professor Kadambot Siddique	Elected and appointed as Member of the Academic Committee of the CORE Academy of Science and Humanities
Professor Sally Thompson	European Geosciences Union Henry Darcy Medal
The Global Farm Platform / UWA Farm Ridgefield	FAO Technical Recognition for Sustainable Livestock Transformation
Manika Rani Debnath	Best Poster Award at the 2nd Global Conference on Sandy Soils 2025
Professor Jacquelin Batley	2025 Scientist of the Year

New postgraduate research students

Name	Topic	School	Supervisor(s)	Funding body
Sanjida Akter	Unravelling the impact of manure management practices on antibiotic resistance and soil health in horticultural farming systems	SMS	Prof Kadambot Siddique and Dr Mia Sultan	UWA and RTP scholarship
Jai Nagarajan (Masters)	Agronomic and Soil Health Benefits of Food Organic Garden Organic (FOGO) Compost as a Soil Amendment in Wheat	SAgE	Prof Kadambot Siddique Prof Nanthi Bolan Dr Zakaria Solaiman	Self-funded
Meena Kharel	Climate change and labour outmigration in an integrated crop-livestock system: The case of Nepal	SAgE	A/Pro Atakelty Hailu, A/Pro Amin Mugeru, Dr Fay Rola-Rubzen	Australian Awards Scholarship (John Alwright Fellowship)
Jaime Phillips	Designing natural capital markets on agricultural land: How do the experiences of southern Australian farmers across the continent help to balance emerging challenges and opportunities in Western Australia?	SAgE	Professor Marit Kragt	UWA and WAARC

Memoranda of Understanding

Name	Date
UWA and The Kerala Agricultural University	January 2025
North South University	March 2025
International Crops Research Institute for the Semi-Arid Tropics	April 2025
Amity University	November 2025
Guangzhou University	December 2025

New research grants

Title	Funding period	Funding body	Investigators
Ripple Effect: A national, grower-led collaboration to increase biodiversity and reduce emissions via the demonstration and accelerated adoption of best-practice water management, strengthening farm water security, productivity and sustainability	2025 - 2028	Dept of Agriculture, Fisheries & Forestry (DAFF)	Assoc Prof Nik Callow, Bonnie Stutsel, Prof Matt Hipsey, Prof Sally Thompson
Weed Management Initiative	2025 - 2030	GRDC	Prof Ken Flower, Dr Michael Ashworth, Dr Danica Goggin, Dr Heping Han, Assoc Prof Michael Renton
Understanding the evolution of blackleg disease resistance genes in canola	2025	UWA	Dr William Thomas, Prof Jacqueline Batley, Mathieu Rousseau-Gueutin, Angela Van De Wouw
Total Carbon Sequestration of Soil and Plant Biomass on Subak Ricefields in Yeh Ho Watershed, Bali, Indonesia	2025-2029	Udayana University	H/Prof Kadambot Siddique, Udayana University
Toward conservation: biological aspect, genetic diversity and ethnobotanical value of local rice in Geriana Kauh Village, Karangasem, Bali	2025	Udayana University	H/Prof Kadambot Siddique, Udayana University
Further Evaluation of Gyplime Effects on Wheat and Canola Growth, Grain Yield, Nutritional Status, and Soil Health in Combination with Organic Amendments Across Diverse Soil Types	2025-2026	Tianqi Lithium Kwinana Pty Ltd	Dr Zakaria Solaiman, H/Prof Kadambot Siddique
Service Agreement-UWA WAAA-DAW2305-003RTX - Effective virus management in grain crops (C1)	2025-2025	GRDC	Prof Martin Barbetti, Dr Mingpei You, Adj Prof Roger Jones
Improving canola nitrogen use efficiency	2025-2028	GRDC	Prof Sergey Shabala, Prof Nanthi Bolan, H/Prof Kadambot Siddique, Prof Wallace Cowling, Dr Sheng Chen, Prof Harvey Millar, Prof Zed Rengel and Prof Jacqueline Batley
Unleashing the potential of Restorer-of-fertility proteins for hybrid crops	2025-2028	ARC	Dr Joanna Melonek, Prof Ian Small
Effective virus management in grain crops	2025	GRDC/DPIRD	Dr Ben Condgon DPIRD; Prof Martin Barbetti, Dr Mingpei You and Adj Prof Roger Jones
Towards precision farm-management using drone-based near-infrared spectroscopy	2025-2026	Department of Education (Australia)	Assoc Prof Dilusha Silva, Prof Lorenzo Faraone, Assoc Prof Gilberto A. Membreno Umana, Prof Charles Musca
ZNE-Ag CRC Project 4020 Agrivoltaics	2025-2026	ZNE-AG CRC LIMITED	Dr Caitlin Moore, Prof Marit Kragt, Dr Pieter Poot, Prof Sally Thompson, Prof Erik Veneklaas, Dr Joanne Wisdom, Dr Kevin Foster

Title	Funding period	Funding body	Investigators
Intensification of northern cattle production in WA enabled by feed products from irrigated cropping	2025-2026	CRC for Developing Northern Australia	Assoc Prof Dominique Blache, Prof Shane Maloney, Prof Phil Vercoe, Dr Luoyang Ding
AcceleTrait Plus: Predicting physiological traits for breeding programs with UAV hyper spectral imagery	2025-2026	GRDC	Assoc/Prof Nic Taylor
WA State Government NCRIS co-investment Plant SynBio	2025-2028	Dept of Job, Tourism, Science and Innovation	Prof Ryan Lister
WA Plant SynBio Innovation Centre	2025-2027	Dept of Education	Prof Ryan Lister
Accelerating Genetic Gain: Utilising the B genome diversity in canola	2025-2029	GRDC	Dr Mathew Nelson, Chris Helliwell, Prof Wallace Cowling, Dr Sheng Chen, Prof Dave Edwards, Prof Jacqui Batley, Junrey Amas, Dr Thomas Bergmann, Thomas McGoram, Ryan Whitford, Matthew Hayden
ARC Training Centre for Smart and Sustainable Horticulture	2025-2029	ARC	Prof Sergey Shabala
ZNE-Ag CRC WMS and milk MIR as proxies for ruminant methane emissions	2025-2027	ZNE-AG-CRC Limited	Dr Zoey Durmic
ZNE CRC Project 1010: Northern Australia low methane feed base program – Phase 1 Discovery	2025-2029	ZNE-AG-CRC Limited	Dr Zoey Durmic
ZNE-Ag CRC Project 3020 LCA for low emissions	2025-2028	ZNE-AG-CRC Limited	Brendan Cullen, Dr Warwick Badgery, Martin Amidy, Dr Caitlin Moore, Dr Ben Biddulph.
Scoping Characteristics of Successful Technology Stacks for Emission Reduction	2025 – 2026	ZNE-AG-CRC Limited	Dr Sarah Whitnall, Prof Marit Kragt
Characteristics for successful technology stacks	2025	ZNE-AG-CRC Limited	Dr Zoey Durmic
ZNE-Ag CRC Project 4030 Insetting Model	2025 – 2027	ZNE-AG-CRC Limited	Prof Marit Kragt, Dr German Puga, Prof Richard Eckard, Dr Bradd Witt, Aaron Wakeley
ZNE CRC Project 1020 (Southern AM Pastures)	2025 - 2028	ZNE-AG-CRC Limited	Dr Zoey Durmic, Dr Joy Vadhanabhuti, Dr Warwick Badgery, Suzanne Boschma.
A Satellite and Aerial Imagery-informed Deep Learning Approach for Enhancing Dwelling Yield Forecasting	2025 - 2026	iMove CRC	Prof Sharon Biermann, Assoc Prof Bryan Boruff, Dr John Duncan, Alex Saunders.

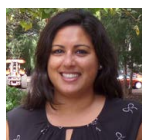
The UWA Institute of Agriculture Staff 2025



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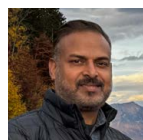
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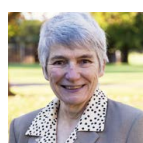
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Institute Management Board (IMB)

The IMB bring together the head of the six UWA schools to provide high level strategic direction and information exchange across agriculture and related areas at the university.



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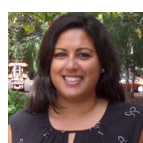


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Theme Leaders

The Theme Leaders co-ordinate research, development and related activities in their respective areas. The Theme Leaders Committee is chaired by Professor Philip Vercoe and Professor Wallace Cowling.

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Sustainable Animal Production Systems

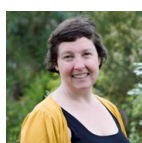


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Water for Food Production



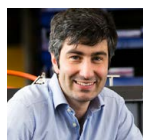
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Engineering for Agriculture

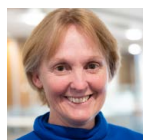


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Industry Advisory Board (IAB)

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



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Rod Birch
Farmer



Ben Biddulph
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Chief Scientist,
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Belinda Eastough
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Dr Hayley Norman
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2025 Publications

Peer Reviewed Journals

1. Abidin N, Barbetti MJ, You MP, and Jones RAC (2025). Seed transmission of Turnip mosaic virus demonstrated unequivocally in a Brassica species. *Plant Disease* doi:10.1094/PDIS-09-24-1981-SC
2. Ahmad M, Sajjad M, Ullah A, Zulfiqar U, Ul-Allah S, Waraich EA, ul Din K, Siddique KHM, and Farooq M (2025). From stress to success: Strategies for improving heat tolerance in wheat. *Journal of Agronomy and Crop Science* **211** doi:10.1111/jac.70048
3. Ahmad W, Sher K, Ditta A, Shah H, Ahmad S, El-Zaidy M, Binobead MA, Iqbal R, Bekhzod S, Abdumannon U, Alisher K, Bakbergen K, & Ozodbek A (2025). Nutritional and phytochemical potential of *Diospyros kaki* L. fruit from the foothills of Hindukush ranges, district Dir Upper, Khyber Pakhtunkhwa, Pakistan. *Genetic Resources and Crop Evolution* doi:10.1007/s10722-025-02398-9
4. Ahmed S, Singh P, Middleton J, Merritt D, Jenkins S, and Nichols P (2025). Impact of seed maturation on the morphology, nutrition, microbiome composition and germinability of subterranean clover (*Trifolium subterraneum*) seeds. *Grass and Forage Science* **80(2)** doi:10.1111/gfs.12725
5. Ai Y, You M P, Yan G, and Barbetti M J (2025). Insights into how glyphosate constrains conidial germination but stimulates morphological transformation of the white leaf spot pathogen *Neopseudocercospora capsellae* in glyphosate-tolerant rapeseed (*Brassica napus*). *Plant Pathology* **0** 1-12 doi:10.1111/ppa.70064
6. Akitaya R, Saito Y, and Pandit R (2025). Assessment of factors influencing farmers' adoption of flood tolerant rice varieties in Nepal. *International Journal of Agricultural Sustainability* **23(1)** doi:10.1080/14735903.2025.2551998
7. Al Hinai MS, Rehman A, Siddique KHM, & Farooq M (2025). The role of trehalose in improving drought tolerance in wheat. *Journal of Agronomy and Crop Science* **211(3)** doi:10.1111/jac.70053
8. Albornoz FE, Prober SM, Steinrucken TV, Bissett A, Mackinnon M, Van Dyke L, Taws N, Linde CC, Gooden B (2025). Changes in soil microbial assemblages, soil chemistry, and vegetation composition associated with *Eucalyptus viminalis* dieback. *Plant and Soil* doi: 10.1007/s11104-025-07407-5
9. Ali S, Tahir S, Hassan SS, Lu M, Wang X, Quyen LTQ, Zhang W, and Chen S (2025). The role of phytohormones in mediating drought stress responses in *Populus* species. *International Journal of Molecular Sciences* **26(8)** doi:10.3390/ijms26083884
10. Aslan-Sungur (Rojda) G, Boersma N, Moore CE, Heaton E, Bernacchi CJ, Vanlooche A (2025). Advances in *Miscanthus x giganteus* planting techniques may increase carbon uptake in the establishment year. *Global Change Biology Bioenergy* **17(1)** doi:10.1111/gcbb.70012
11. Aslan-Sungur GR, Boersma N, Moore CE, Heaton E, Bernacchi CJ, Vanlooche A (2025). Advances in *Miscanthus x giganteus* planting techniques may increase carbon uptake in the establishment year. *Global Change Biology Bioenergy* **17** 1 doi: 10.1111/gcbb.70012
12. Aswathi K P R, Ul-Allah S, Puthur J T, Siddique K H M, Frei M, & Farooq M (2025). The Plant Mind: Unraveling abiotic stress priming, memory, and adaptation. *Physiologia Plantarum*, 177:e70372. doi:10.1111/ppi.70372
13. Babington S, Ding L, Tilbrook AJ, Maloney SK, & Blache D (2025). A comparison of normalization methods for the expression of genes associated with oxidative stress in the liver of sheep. *BMC Genomic Data* **26** Article 53 doi:10.1186/s12863-025-01345-y
14. Babington S, Ding L, Tilbrook AJ, Maloney SK, Kho EA, Fernandes JN, & Blache D (2025). Identifying biomarkers of sheep welfare using a metabolic discrepancy model. *Scientific Reports* **15(1)** doi:10.1038/s41598-025-97993-2
15. Bakshi L, Haslam-McKenzie F, Bolleter J, and Wilkinson G (2025). Sticky places for immigrants in regional Australia – a correlational analysis. *Journal of Population Research* **42** 20 doi:10.1007/s12546-025-09372-3
16. Blakely B, Moore CE, Pederson TL, Gibson CD, Benson MC, Dracup E, Bernacchi CJ (2025). Climate forcing of bioenergy feedstocks: Insights from carbon and energy flux measurements. *Global Change Biology Bioenergy* **17** 4 doi: 10.1111/gcbb.70026
17. Bolan N, Mukherjee S, Sharma S, Bolan S, Yuan J, Yang S, Peacock C, Otero-Fariña A, Adeleke R, Obi L, Pang J, and Siddique K H M (2025). Exudates of carboxylates by roots and their implications for nutrient, contaminant and carbon dynamics in soil. *Critical Reviews in Plant Sciences* **1**-23 doi:10.1080/07352689.2025.2549655
18. Bolan S, Sharma S, Mukherjee S, Gomez Isaza DF, Rodgers EM, Zhou P, Hou D, Scordo F, Chandra S, Siddique KHM, and Bolan N (2025). Wildfires under changing climate, and their environmental and health impacts. *Journal of Soils and Sediments* **0(0)** doi:10.1007/s11368-025-04020-y
19. Cao N, Zha L, Li Q, Hu W, Pang J, Zhou Z, Zhao W, & Meng Y (2025). Simultaneously improving soil AMF community and phosphorus uptake by cotton plants by continuous straw incorporation and optimizing phosphorus management. *Land Degradation & Development* **36(8)** doi:10.1002/ldr.5520
20. Chandhani R, Qin T, Ye H, Hu H, Panjvani K, Tokizawa M, Mora Macias J, Armenta Medina A, Bernardino KC, Pradier P-L, Banik P, Mooney A, Magalhaes JV, Nguyen HT, Kochian LV (2025). Application of an improved 2-dimensional high-throughput soybean root phenotyping platform to identify novel genetic variants regulating root architecture traits. *Plant Phenomics* **5** doi:10.34133/plantphenomics.0097
21. Chauhan YS, Anwar MR, Richards MF, Ip RHL, Luckett DJ, Lake L, Sadras VO, Siddique KHM (2025). Accounting for soil water improves prediction of lentil phenology for improved frost and heat stress management. *European Journal of Agronomy*, 164 127486 doi: 10.1016/j.eja.2024.127486
22. Chen J, Cui H, Li Z, Yu H, Yu Q, Li X (2025). Increase in IAA levels by EPSPS copy number variation relates to fitness advantage in *Eleusine indica*. *Pest Management Science* doi:10.1002/ps.8637
23. Chen J, Huang Y, Zhou X, Wen Y, Chen Q, Gao H, Sun D, Wang L, Ming A, & Lambers H (2025). Decreased management intensity and mixed planting enhance *Eucalyptus* productivity through improved soil quality under eco-silviculture management in southern China. *Plant and Soil* **516** 2157-2177 doi:10.1007/s11104-025-07853-1
24. Chen S, Zhang Y, Ma J, Bai M, Long J, Liu M, Chen Y, Guo J, & Chen L (2025). Contribution of soil Microbial Necromass Carbon to Soil Organic Carbon fractions and its influencing factors in different grassland types. *EGUsphere* doi:10.5194/egusphere-2025-1122
25. Chen W, Liao Y, Bai D, Yu Q, Bai L, Pan L (2025). First case of glyphosate resistance in *Polypogon fugax* possible involvement of P450-based mechanisms. *Pest Management Science* **81(6)** doi: 10.1002/ps.8704
26. Chen X, Liu G, Liu B, Chen T, Li Y, Chen W, Pang J, Siddique KHM, and Chi D (2025). Zeolite amendment enhances grain yield and mitigates greenhouse gas emissions in an intensive aerobic rice system. *Field Crops Research* **327** doi:10.1016/j.fcr.2025.109884
27. Cook DC, Taylor AS, Gardiner PS, Pires RN, McKirdy HLR, Holmes KW, & Spafford H (2025). Potential economic impact of grapevine phylloxera (Hemiptera: Phylloxeridae) on Western Australian winegrapes. *Australian Journal of Grape and Wine Research* **1** doi:10.1155/ajgw/4815715
28. Cui N, Qi T, Chen Z, Wang J, Ma J, Liu E, Meruyert M, Jia Z, Siddique K H M, and Zhang P (2025). Legume rotation with optimal nitrogen management enhances subsequent winter wheat productivity and soil ecosystem multifunctionality: a case study in semi-humid regions. *Plant and Soil* doi:10.1007/s11104-025-07711-0

29. Dai J, Shi Y, Zed R, Sun B, Shen J, Zhang F, Jin K (2025). Adaptation of deep-rooted maize genotype to compacted soil: Synergy of root mechanical properties anatomical traits and PIEZO1 gene regulation. *Soil & Tillage Research* **252** doi: 10.1016/j.still.2025.106620
30. Dao J, Xing Y, Chen C, Chen M, Wang Z, Chen Y (2025). Changes in shoot and root adaptations of fibrous-root and taproot crops in response to different drought types: A meta-analysis. *Agricultural Water Management* **309** doi: 10.1016/j.agwat.2025.109320
31. De Oliveira VH, Dobrowolski MP, Duddigan S, Tibbett M (2025). Edaphic legacy of phosphorus fertiliser in the restoration of the biodiverse Kwongan ecosystem in ultra-low P soils *Catena* **254** doi: 10.1016/j.catena.2025.108961
32. Decurgez C G, Schnyder H, Gundel P E, Striker G G, Biganzoli F, Fazio L, and Casas C (2025). Foliar fungal endophyte triggers host ecophysiological and morphological responses to drought and waterlogging. *Plant and Soil (online first)* doi:10.1007/s11104-025-07634-w
33. Devkota KP, Devkota M, Mabhaudhi T, Nangia V, Attaher S, Boroto RJ, Timsina J, Siddique KHM (2025). A blueprint for building resilience and food security in MENA and SSA drylands: Diversifying agriculture with neglected and underutilized species. *Food and Energy Security*, **2025** doi: 10.1002/fes3.70046
34. Ding J, Muga A, & Zhao X (2025). Outsourcing fertilizer mechanization services to different types of service providers: assessing the impact on fertilizer application for wheat producers in China. *Agribusiness* doi:10.1002/agr.22048
35. Eckersley J, Moore CE, Thompson SE, Renton M, & Grierson PF (2025). Separating leaf area index from plant area index using semi-supervised classification of digital hemispheric canopy photographs: a case study of dryland vegetation. *Agricultural and Forest Meteorology* **363** doi:10.1016/j.agrformet.2025.110395
36. Eichelsbacher S, Luksch CR, Bienert GP, Alcock TD, Steppe K, Marcelis LFM, Orsini F, Rosenqvist E, Lambers H, Runkle E, Lawson T, and Asseng S (2025). What is the limit of vertical farming productivity? *Food and Energy Security* **14** e70061 doi:10.1002/fes3.70061
37. Fan J W, Chen M, Tian F, Yao R, Turner N C, Yang L, Fang W Y, Abbott L, Li F M, and Du Y L (2025). Arbuscular mycorrhizal fungi enhance alfalfa production by changing root morphology and physiology. *Journal of Experimental Botany* **eraf335** doi:10.1093/jxb/eraf335
38. Fan Z, Ku Y, Li Z, Dang K, Gao L, Li H, Chen Y, Yin L, & Zhang S (2025). Microbially mediated rhizospheric phosphorus turnover promotes wheat yield by enhancing phosphorus bioavailability. *Agriculture Ecosystems & Environment* **387** doi:10.1016/j.agee.2025.109618
39. Farooq M, Frei M, Zeibig F, Pantha S, Özkan H, Kilian B, and Siddique KHM (2025). Back into the wild: harnessing the power of wheat wild relatives for future crop and food security. *Journal of Experimental Botany* doi:10.1093/jxb/eraf141
40. Feddema K, Schepis D, Tarabashkina L, and Purchase S (2025). Blurred vision: understanding barriers to initiating collaborative market driving. *European Journal of Marketing* doi:10.1108/EJM-12-2023-0874
41. Garg V, Barmukh R, Huang Y, Chitkineni A, Hobson K, Yang B, Jia Y, Bi S, Kaur S, Asif MA, Hayden M, Norton S, Sharma DL, Siddique KHM, Liu X, Li C, and Varshney RK (2025). An Australian chickpea pan-genome provides insights into genome organization and offers opportunities for enhancing drought adaptation for crop improvement. *Plant Biotechnology Journal* doi:10.1111/pbi.70192
42. Gholizadeh A, Mehraei S, Hanifei M, Akbarpour O (2025). Evaluation of salinity tolerance in wheat: a novel approach using artificial neural networks and rank sum-integrate selection index methods. *Acta Physiologiae Plantarum* **47**(1) doi:10.1007/s11738-024-03754-5
43. Gill A R, Miller T K, Wijeweera S, Herrero E, Massa G D, Mortimer J C, Webb A A R, Millar A H, and Gilliam M (2025). Turbocharging fundamental science translation through controlled environment agriculture. *Trends in Plant Science* doi:10.1016/j.tplants.2025.08.014
44. Goggin D, Owen M, Busi R, and Flower K (2025). Limited effect of seed dormancy on the efficacy of preemergence herbicides in rigid ryegrass (*Lolium rigidum*). *Weed Science* **73**(1) doi:10.1017/wsc.2025.10042
45. Goggin DE, Cawthray GR, Flematti GR, Busi R (2025). Bixlozone metabolism in crop and weed species: A basis for selectivity and evolved resistance. *Journal of Agricultural and Food Chemistry* **73** **13** doi: 10.1021/acs.jafc.5c00162
46. Gong J, Zhang S, Li Y, Lambers H, Zhang W, Zhang S, Dong X, Yang G, Wang R, Yan C, & Wang T (2025). Increasing phosphorus availability reduces grassland soil N₂O emission: Plants and microbes move from mutualism to self-reliance. *Agriculture Ecosystems & Environment* **389** doi:10.1016/j.agee.2025.109695
47. Guan R, Li Y, Siddique KHM, Jia Y, Jiang F, Li L, & Biswas A (2025). Dual impact of single acidified biochar application on saline-alkaline soil: short-term salinization risks and persistent nutrient benefits. *Soil & Tillage Research* doi:10.1016/j.still.2025.106745
48. Gui XY, Li YJ, Yu HY, Zhang WT, Deng XQ, Zhang ZF, Hua GH, Li H, & Kang HM (2025). Short communication: evaluating laying curve models and estimating genetic parameters for egg production traits in chickens. *Animal* **19**(4) doi:10.1016/j.animal.2025.101465
49. Guo H, Sun L, Wu S, Siddique KHM (2025). The process and driving mechanism of abandoned terraces in mountain region at the watershed scale. *Ecological Engineering* doi:10.1016/j.ecoleng.2025.107582
50. Gurung SK, Mikan BS, Jenkins SN, Rengel Z, Siddique KHM, & Solaiman ZM (2025). Turning waste into resilience: the effect of black soldier fly larvae frass and wheat straw biochar on bell pepper growth, soil fertility and rhizosphere bacteria under water stress. *Plant and Soil* doi:10.1007/s11104-025-07672-4
51. Gusmao M, Fernandes Z, dos Santos J, Archontoulis VS, & Siddique KHM (2025). Integrating farmers' views, field soil erosion assessment, and pot experiments to evaluate different agroforestry systems in Timor-Leste. *Agroforestry Systems* **99**(3) doi:10.1007/s10457-025-01147-2
52. Haider F, Ain N, Siddique KHM, Farooq M, Li Y (2025). Enhancing bread wheat resilience to cadmium and drought stress: insights from physiological, morphological, and transcriptomic responses to biochar and 24-epibrassinolide application. *Biochar* **2025** doi:10.1007/s42773-025-00457-z
53. Haider FU, Virk AL, Zhou S, Ain N, Ramos Aguila LC, Siddique KHM, Farooq M, Li Y (2025). Impact of silicon nitride nanoparticles on soil organic carbon dynamics in subtropical evergreen forest ecosystems of China an incubation study. *Science of The Total Environment* **965** **178682** doi:10.1016/j.scitotenv.2025.178682
54. Halder T, Bhoite R, Islam S, Yan G, Siddiqui M N, Kayess M O, and Siddique K H M (2025). Proteomics in allopolyploid crops: stress resilience, challenges and prospects. *Proteomes* **13**(4) doi:10.3390/proteomes13040060
55. Han E, Bultynck L, Lambers H, Gregory P (2025). Editorial: Vision for the Methods Papers in Plant and Soil. *Plant and Soil* **509** 1-2 doi: 10.1007/s11104-025-07275-z
56. He J, Palta J A, Jin Y, and Turner N C (2025). Interaction of phosphorus supply and water deficits on the yield, protein and oil content, and nitrogen fixation of soybean (*Glycine max* (L.) Merr.). In: Sparks D L (ed.) *Advances in Agronomy* **189**: 211-259. Academic Press. doi:10.1016/bs.agron.2024.08.002
57. He Q, Li L, Shi Y, Feng P, Liu K, Zhang S, Liu DL, Wang Z, Harrison MT, Li S, Yu Q, and Siddique KHM (2025). Soil organic carbon improvement for mitigating crop yield losses under global warming. *European Journal of Agronomy* **170**:127739 doi:10.1016/j.eja.2025.127739
58. He Q, Lu C, Cowie A, Zhao S, Liu D, Yi B, Shi L, Zhang S, Qiu T, Shi Y, Huete A, Siddique KHM, Yu Q & Li L (2025). Optimizing cover cropping application for sustainable crop production. *Nature Food* **6**(1) doi:10.1038/s44264-025-00050-8
59. He T, Sun G, He S, Zhang Z, Dong J, Zhu X, Dai J, Wang K, Xing J (2025). Full-length transcriptome analysis of *Sesbania cannabina* stem response to waterlogging stress. *Agronomy* **15**(5):1197 doi: 10.3390/agronomy15051197
60. He Y, He K, Mai J, Ou M, Chen L, Li Y, Wan T, Gu L, Shabala S, Li X, Li Y, Yu M (2025). Boron controls apical dominance in pea (*Pisum sativum*) via promoting polar auxin transport. *Physiologia Plantarum* **177**(1). doi:10.1111/ppi.70056
61. Hu H, Zhao J, Thomas WJW, Batley J, Edwards D (2025). The role of pangenomics in orphan crop improvement. *Nature Communications* **16**(1) doi:10.1038/s41467-024-55260-4

62. Hu X, Chen S, Ping X, Siddique KHM, and Cowling WA (2025). Proteomic analysis reveals differentially abundant proteins involved in post-pollination responses to heat stress in *Brassica napus*. *Journal of Proteomics* **319**:105481 doi:10.1016/j.jprot.2025.105481
63. Hu Y, Ma P, Yang Z, Liu S, Li Y, Li L, Wang T, & Siddique KHM (2025). The responses of crop yield and greenhouse gas emissions to straw returning from staple crops: a meta-analysis. *Agriculture* **15**(4) doi:10.3390/agriculture15040408
64. Huang T, Sun R, Wu Q, Zhang X, Li J, Zhou B, Liao Y, Qin X, Reynolds M, & Siddique KHM (2025). Assessment of genetic improvements in wheat yield and nitrogen use efficiency under different nitrogen input levels: A global perspective. *European Journal of Agronomy* **171** doi:10.1016/j.eja.2025.127813
65. Huang T, Yang M, Zhang M, Yang X, Wu Q, Pan X, Dang P, Wang S, Yang N, Zhang M, Han X, Wang X, Wang W, Sun R, Zhang X, Reynolds M, Song F, Joseph CO, Pan Y, Nazarov K, Siddique KHM, and Qin X (2025). Crop management measures to mitigate negative impacts of late sowing on winter wheat production in China: a meta-analysis. *Journal of the Science of Food and Agriculture* **105**(10) doi: 105:5280–5290
66. Huang T, Zhang Z, Sun R, Wu Q, Zhong X, Siddique KHM, Qin X, & Zhao X (2025). Wheat genetic improvement affects the fate of nitrogen uptake and utilization. *Field Crops Research* doi:10.1016/j.fcr.2025.110078
67. Huang T, Zhang Z, Zhong X, Sun R, Zhao X, Wu Q, Wang S, Yang X, Qin X, and Siddique K H M (2025). Breeding and nitrogen management shape root morphology and water use efficiency in wheat in the Huang-Huai-Hai region of China. *Plant and Soil* (online first) doi:10.1007/s11104-025-07823-7
68. Hui X, Luo L, Chen Y, Palta JA, & Wang Z (2025). Zinc agronomic biofortification in wheat and its drivers: a global meta-analysis. *Nature Communications* **16**(1) doi:10.1038/s41467-025-58397-y
69. Hussan M U, Hussain S, Farooq M, Habib-Ur-Rahman M, Jinjin W, Zahra N, Wang Q, Yan M, Roetter R P, and Siddique K H M (2025). Interactive effect of biochar and nano-calcium oxide on alfalfa cadmium detoxification: boosting antioxidant defense, regulating gene expression, and remediating soil. *Journal of Cleaner Production* **533** doi:10.1016/j.jclepro.2025.146852
70. Iqbal M S, Taylor C M, Kotula L, Malik A I, and Erskine W (2025). Dissecting the genetic and phenotypic basis of salinity tolerance in mungbean: insights from multi stage phenotyping, GWAS and genomic prediction. *Theoretical and Applied Genetics* **138**(9) doi:10.1007/s00122-025-04983-z
71. Islam M M, Siddique K H M, & Solaiman Z M (2025). Nutrient profiles and bioavailability in industrial hemp (*Cannabis sativa* L.) seeds from diverse provenances. *Sustainability*, 17:5844. doi:10.3390/su17135844
72. Janke C, Kirkegaard J, Hunt J, Barton L, Bell L, Karunaratne S, Macdonald LM, Pasut C, Stockmann U, Tavakkoli E, Vadakattu G, Wasson A, and Farrell M (2025). The pros and cons of increasing soil organic matter in dryland cropping systems. *Crop & Pasture Science* **76** doi:10.1071/CP24257
73. Jeddi K, Abbes K, Lassoued M, Jeddi K, Hessini K, Siddique KHM, Chermiti B (2025). Attractiveness of Mediterranean native plants to arthropod natural enemies and herbivores. *Arthropod-Plant Interactions* **19** doi:10.1007/s11829-025-10204-7
74. Jeddi K, Reguei A, Galal T, Siddique KHM, and Hessini K (2025). Potential allelopathic effects of two multipurpose trees on germination, seedling performance, and antioxidant activity of alfalfa in Mediterranean arid lands. *Russian Journal of Plant Physiology* **72**(1) doi:10.1134/S1021443724606852
75. Jeddia K, Siddique K H M, and Hessini K (2025). Impact of salinity on plant growth, photosynthesis, cell wall elasticity and osmotic adjustment in Damask rose. *Russian Journal of Plant Physiology* **72** 171 doi:10.1134/S1021443725602630
76. Jha U C, Naik Y D, Priya M, Nayyar H, Sofi P A, Beena R, Kudapa H, Atta K, Thudi M, Prasad P V V, and Siddique K H M (2025). Chickpea (*Cicer arietinum* L.) battling against heat stress: plant breeding and genomics advances. *Plant Molecular Biology* **115**(1) doi:10.1007/s11103-025-01628-z
77. Jha U C, Warburton M L, Nayyar H, Chatti D, Ghatak A, Siddique K H M, and Vara Prasad P V (2025). Heat stress induced metabolomic shifts in chickpea (*Cicer arietinum* L.) flowers insights from contrasting genotypes. *Scientific Reports* **15** doi:10.1038/s41598-025-21697-w
78. Jha U C, Warburton M L, Nayyar H, Siddique K H M, and Vara Prasad P V (2025). Metabolomic and lipidomic changes in heat stressed chickpea seeds. *Frontiers in Plant Science* **16** doi:10.3389/fpls.2025.1668751
79. Jha U C, Warburton M, Nayyar H, Shafi S, Ciampitti I A, Udgata A R, Siddique K H M, and Prasad P V V (2025). Influence of elevated temperature on the nutritional profile of Chickpea (*Cicer arietinum* L.) seeds. *PLoS ONE* doi:10.1371/journal.pone.0330230
80. Jha UC, Shafi S, Tallury S, Nayyar H, Ciampitti IA, Siddique KHM, Prasad PVV (2025). Differential physiological and yield responses of selected mung bean (*Vigna radiata* (L.) R. Wilczek) genotypes to various high-temperature stress regimes. *Scientific Reports* **15**, 1034 (2025) doi: 10.1038/s41598-024-84615-6
81. Jia Y, Li Y, Biswas A, Pang J, Song X, Yang G, Hou Z, Luo H, Xie X, Ishchanov J, Chen J, Ju J, Siddique KHM (2025). Evaluation of cotton planting suitability in Xinjiang based on climate change and soil fertility factors simulated by coupled machine learning model. *Resources, Conservation and Recycling* **165** doi:10.1016/j.resenv.2025.100200
82. Jia Y, Sun Y, Zhang D, Yang W, Pang J, Siddique KHM, and Qu Z (2025). Mitigation of greenhouse gas emissions using straw biochar in arid regions of Northwest China: Evidence from field experiments. *Agronomy* **15**(5) doi:10.3390/agronomy15051007
83. Jiang F, Li Y, Xiao C, Li L, Siddique KHM, Yang L, Li C, & Hu W (2025). Combined application of irrigation and biochar increased sugar beet yield by optimizing source-sink relationships. *Plant Soil* doi:10.1007/s11104-025-08139-2
84. Jiao Z, Hu Z, Chen Y, Huang Z (2025). Carbon and nutrient dynamics during decomposition of Chinese fir (*Cunninghamia lanceolata*) stumps in subtropical plantations. *Land Degradation & Development* doi: 10.1002/ldr.5618
85. Jones RAC (2025). Australian cool-season pulse seed-borne virus research: 2. Bean yellow mosaic virus. *Viruses* **17**(5) doi:10.3390/v17050668
86. Juthee S A, Hosenuzzaman M, Solaiman Z M, Hosen M A, Faruqe T, and Hossain M A (2025). Eco friendly synthesis, characterization, and application of silver nanoparticles to extend the vase life of gerbera (*Gerbera hybrida*). *Postharvest Biology and Technology* **229** doi:10.1016/j.postharvbio.2025.113711
87. Kang M, Xu M, Guo Y, Qiao L, He X, and Lan X (2025). Strategies to narrow down rainfed maize yield gap by decomposing gap sources across the East Loess Plateau of China. *Field Crops Research* **331** doi:10.1016/j.fcr.2025.109997
88. Karunanayake L, Etampawala T, de Silva DJ, Bandara J, Rajapaksha AU, & Vithanage M (2025). Role and potential of biochar as a sustainable alternative reinforcing filler to carbon black in rubber composites. *Biochar* **7**(1) doi:10.1007/s42773-025-00429-3
89. Kaur S, Padhiar D, Jha U C, Kumar S, Sharma K D, Parida S K, Siddique K H M, Vara Prasad P V, and Nayyar H (2025). Nitric oxide mediated modulation of reproductive resilience under cold stress in chickpea. *Frontiers in Plant Science* **16** doi:10.3389/fpls.2025.1679156
90. Kaur S, Padhiar D, Singh M, Parida SK, Jha UC, Sharma K, Prasad PV, Siddique KHM, & Nayyar H (2025). Assessing cold stress resilience in wild chickpea accessions using physiological, biochemical, and reproductive traits. *Scientific Reports* **15**:26714 doi:10.1038/s41598-025-09162-0
91. Kelly JM, Bohman B, Bennett D, Taylor NL (2025). Rapid dough making quality analysis of wheat flour using Fourier transform infrared spectroscopy and chemometrics. *Food Chemistry* doi:10.1016/j.foodchem.2025.143335
92. Khan KS, Naveed M, Ditta A, Alam T, Mumtaz MZ, Abbas A, Manzoni S, & Li L (2025). Soil C/P stoichiometry mediated microbially driven phosphorus mobilization: New insight in soil P management. *Journal of Soil Science and Plant Nutrition* **25** 7691–7709 doi:10.1007/s42729-025-02624-4
93. Kharel S, Foster K, Guthrie M, & Kingwell R (2025). Farm profit impacts of consecutive drought years under climate scenarios in Southwestern Australia. *Australian Farm Business Management Journal* **22**(1)

94. Kidd D R, Enkhat B, Wisdom J M B, Kragt M E, Jenkins S N, and Ryan M H (2025). Black soldier fly frass greatly improves growth of four crops in a fertilised sandy soil. *Journal of Cleaner Production* **520** 146046 doi:10.1016/j.jclepro.2025.146046
95. Kingwell R (2025). Challenges and changes in Australia's grain production and supply chains. *Australian Journal of Agricultural and Resource Economics (online first)* doi:10.1111/1467-8489.70029
96. Krishnankutty J, Sasidharan LP, Raju RK, Kaladharan N, UI Purath A, Sugathan V, Blakeney M, and Siddique KHM (2025). Traditional rice varieties, consumer segmentation, and preferences: a case study from Kerala, India. *Sustainability* **17**:5467 doi:10.3390/su17125467
97. Kumar M, Kumar R, Sharma S, Mukherjee S, Bolan S, Shrivastava A, Hettiarachchi M, Siddique KHM, & Bolan N (2025). Microplastics pollution modulating soil biological health – A review. *Soil Use and Management* **41**(e70009) doi:10.1111/sum.70009
98. Kumar M, Mrunalini K, Zhou Z, Modi RU, Bolan S, Rao CS, Braun M, Wrigley O, Li Y, Wang L, Leri A, Dhupper R, Siddique KHM, and Bolan N (2025). Sources, distribution and migration of micro-nano-plastics from terrestrial to aquatic environments and its environmental and health impacts: a systematic review. *Journal of Soils and Sediments* doi:10.1007/s11368-025-04042-6
99. Kumar N, Bharadwaj C, Patil B S, Sahu S, Roorkiwal M, Siddique K H M, & Varshney R K (2025). Development and validation of candidate gene specific markers for salinity responsiveness in chickpea (*Cicer arietinum* L.). *Indian Journal of Genetics and Plant Breeding*, 85(2):271–279. doi:10.31742/ISGPB.85.2.12
100. Kumari S, Naaz M, Siddique KHM, and Khan MIR (2025). GABA-dependent ethylene response mitigates salt-induced growth and yield inhibition through stabilizing carbon energy, nutrients accumulation and metabolomic fingerprinting in wheat. *Plant Physiology and Biochemistry* doi:10.1016/j.plaphy.2025.110020
101. Li F, Duan X, Zhou J, Feng S, Du W, He X, Peng H, Li H, Ahmad S, and Pan B (2025). Inhibited vertical mobility of biochar derived dissolved organic matter under low intensity rainfall: role of mineral retention. *Biochar* **7** doi:10.1007/s42773-025-00484-w
102. Li L, Wang B, Feng P, Lu C, Jägermeyr J, Asseng S, Luo JJ, Harrison MT, He Q, Liu K, Liu DL, Li Y, Feng H, Yang G, Zhao C, Siddique KHM, Tian H, and Yu Q (2025). Global warming increases the risk of crop yield failures driven by climate oscillations. *One Earth* doi:10.1016/j.oneear.2025.101318
103. Li MY, Wang W, Yin HH, Chen Y, Ashraf M, Tao HY, Li SS, Wang WY, Yang CL, Xiao YL, Zhu L, Xiong YC (2025). The functional role of arbuscular mycorrhizal fungi in enhancing soil organic carbon stocks and stability in dryland. *Soil & Tillage Research* **248** doi:10.1016/j.still.2024.106443
104. Li S, Li Y, Zhang G, Wang L, Song M, Fan Y, and Siddique K H M (2025). Compound dry/wet and hot extremes decreased wheat/maize yield revealed by SHAP-RF and R-Vine Copula. *Field Crops Research* **334** doi:10.1016/j.fcr.2025.110161
105. Li T, Zheng J, Li Y, Mou Z, Zhang J, Wu W, Wang T, Wang F, Wang J, Hui D, Wu D, Yuan Y, Lambers H, Sardans J, Penuelas J, & Liu Z (2025). Divergent chemical responses of soil carbon and phosphorus to nutrient addition mediated by functional carbon pools in tropical forests. *Plant and Soil* doi:10.1007/s11104-025-08102-1
106. Li W, Gong Y, Guo J, Wang J, Lv Z, Liu J, Siddique K H M, and Mao H (2025). Effects of biodegradable and conventional microplastics on soil-mung bean system under ZnO nanoparticle stress. *Plant and Soil* **2025** doi:10.1007/s11104-025-07883-9
107. Li X, Du Y, Yan T, Wang Y, Lu Y, Gu X, Niu W, and Siddique K H M (2025). Nitrogen application under aerated irrigation mitigated drought stress by improving leaf carbon and nitrogen reserves in tomato. *Land Degradation and Development* **36**(14) doi:10.1002/ldr.5667
108. Li X, Tian C, Bu C, Gao P, Wu S, Fan J, Zhang W, Pang J, Wei Y, Siddique KHM, and Luo H (2025). Soil multifunctionality responses to warming and nitrogen addition and the mediating bacteria vary by biocrust type. *European Journal of Soil Science* **76**:e70146 doi:10.1111/ejss.70146
109. Li XL, Sun H, Zhou J, Chen Y, Du HQ, Ming YX, Wu S, Lambers H (2025). Acidification associated with plant phosphorus-acquisition strategies decreases nutrient cycling potential of rhizosphere bacteria along the Hailuoguo post-glacial chronosequence. *Plant and Soil* doi: 10.1007/s11104-025-07445-z
110. Li Y, Liang J, Wang H, and Siddique KHM (2025). Editorial: Biochar in agroecosystems: optimizing soil fertility and crop productivity. *Frontiers in Sustainable Food Systems* **9** doi:10.3389/fsufs.2025.1609784
111. Li Y, Liu X, Lu J, Feng H, Chen J, Yang Q, Zhou L, Li N, Siddique KHM, and Liang J (2025). Soil extracellular enzymes, soil carbon and nitrogen storage under straw return: A data synthesis. *Industrial Crops and Products* **228** doi:10.1016/j.indcrop.2025.120884
112. Li Y, Lu J, Feng H, Chen J, Yang Q, & Siddique KHM (2025). Soil cellulase activity responds to straw return and correlates with soil organic carbon dynamics: A global meta-analysis. *Plant Soil* doi:10.1007/s11104-025-08223-7
113. Li Y, Sun J, You J, Lv C, Yang S, Wu M, Zhang Z, Niu W, Huang S, Siddique KHM, Gao Q, Li G (2025). Quantification of water uptake by winter wheat roots under different dieline burial depths using hydrogen and oxygen stable isotopes. *Agricultural Water Management* **109983** doi:10.1016/j.agwat.2025.109983
114. Li Y, Wang X, Gong F, Guan Y, Jiao Y, Chi D, Wu Q, O'Connor J, Bolan N S, and Siddique K H M (2025). Alternate wetting and drying irrigation with biochar based struvite enhances phosphorus availability, reduces phosphorus loss potential, and improves yield and water use efficiency in paddy systems. *Agricultural Water Management* **319** doi:10.1016/j.agwat.2025.109797
115. Li Y, Wang X, Guan Y, Wu Q, Chi D, Bolan NS, Siddique KHM (2025). Nano-biochar-based struvite with urea reduces ammonia emission and warming potential, promotes nitrogen utilization balance, and improves net ecosystem economic benefits of paddy fields. *Field Crops Research* **326** doi:10.1016/j.fcr.2025.109872
116. Li Y, Zhao S, Liu G, Li J, Siddique KHM, & Zhao D (2025). Agronomic traits, nutrient accumulation, and their correlations in wheat, as affected by nitrogen supply in rainfed coastal saline soils. *Plants* **14**(7) doi:10.3390/plants14071022
117. Li Z, Ren L, Pan H, Ji Y, Zhang N, Meruyert M, Assiyae A, Zhang W, Liu E, Siddique KHM, Ding R, Jia Z, Wang Y, Liu Z, and Zhang P (2025). Ridge-furrow film mulching combined with biochar addition enhances maize productivity and reduces nitrogen loss, but increases soil moisture consumption in semi-arid areas. *Plant and Soil* **0**(0) doi:10.1007/s11104-025-07386-7
118. Liang Q, Zhang T, Kuang Y, Jiliu Y, Cheng Y, Gao W, Feng H and Siddique KHM (2025). Ryegrass intercropping with residue incorporation enhances apple yield and reduces nitrogen loss despite minimal water-nitrogen competition on the Loess Plateau, China. *Agriculture, Ecosystems & Environment* **389** doi:10.1016/j.agee.2025.109700
119. Liu B, Yuan Z, Guo J, Wu S, Feng H, Bu C, and Siddique K H M (2025). Identification and mapping of gully using machine learning and deep learning algorithms in the loess hilly and gully region in China. *International Soil and Water Conservation Research (online first)* doi:10.1016/j.iswcr.2025.10.003
120. Liu S, An T, Gao Y, Kuang Q, Xu B, Zhang S, Deng X, Zhao T, Lam H-M, Shabala S, & Chen Y (2025). Soybean genotypes with contrasting root system size differ in saline-alkaline tolerance. *Journal of Agronomy and Crop Science* **211**(2) doi:10.1111/jac.70040
121. Liu Z, Zhao C, Zhang N, Wang J, Li Z, Uwiragiye Y, Fallah N, Crowther TW, Huang Y, Xu Y, Zhang S, Kuzyakov Y, Siddique KHM, Jia Z, Cai Z, Chang SX, Xu M, Müller C, and Cheng Y (2025). Degradable film mulching increases soil carbon sequestration in major Chinese dryland agroecosystems. *Nature Communications* **16**:5029 doi:10.1038/s41467-025-60036-5
122. Lu X, Sun J, Pan G, Qi W, Zhang Z, Xing J, Gao Y (2025). Ball-milling-modified biochar with additives enhances soil Cd passivation increases plant growth and restrains Cd uptake by Chinese cabbage. *Horticulturae* **11** 2 doi: 10.3390/horticulturae11020168

123. Luo H, Liu G, Qi T, Cui N, Xie B, Xiang Y, Liu E, Meruyert M, Assiya A, Jia Z, Siddique KHM, and Zhang P (2025). Substituting soybean for summer maize with optimal nitrogen fertilization enhances subsequent wheat yield and nitrogen use efficiency in semi-humid regions. *Soil and Tillage Research* **252** doi:10.1016/j.still.2025.106594
124. Luo L, Hui X, Zheng X, Wang Z, Chen Y, and Wu J (2025). Integrated straw return and nitrogen management improve grain zinc in wheat grown on calcareous soils. *Field Crops Research* **334** doi:10.1016/j.fcr.2025.110139
125. Ma J, Chen L, Pang D, Wu M, Zhang Y, Chen Y, and Li X (2025). Aridity index explains the accumulation of soil organic carbon sources in grassland ecosystem. *European Journal of Soil Science* **76(4)** doi:10.1111/ejss.70158
126. Ma L, Li G, Niu W, Du Y, and Siddique KHM (2025). Nitrogen reduction combined with organic fertilizer: key practices to enhance soil quality and crop productivity while mitigating N₂O emissions. *Land Degradation & Development* (online first) doi:10.1002/ldr.70282
127. Ma N-J, Zhang Y-Q, Xu L-W, Pang J, Chen Y, Xu Q, He J, Lambers H (2025). Crop domestication has increased phosphorus-acquisition capacity but restricted root plasticity under phosphorus-limited conditions. *Rhizosphere* **34** doi: 10.1016/j.rhisph.2025.101087
128. Markie E, Khoddami A, Liu SY, Chen S, and Tan DKY (2025). The impact of heat stress on canola (*Brassica napus* L.) yield, oil, and fatty acid profile. *Agronomy* **15(7)** doi:10.3390/agronomy15071511
129. Matthews S, Ali A, & Siddiqui Y (2025). Nano-encapsulated biostimulant enhances growth and postharvest quality of chili peppers (*Capsicum annum*). *Scientia Horticulturae* **340** doi:10.1016/j.scienta.2024.113920
130. Mburu M, Mugeru A, Mburu J, Nyikal R, and Ndambi O A (2025). Climate smart dairy practices: the role of practice clusters in enhancing the performance of dairy farms in Kenya. *Agribusiness* doi:10.1002/agr.70021
131. Mercer GD, Mickan BS, Gleeson DB, Walker E, Krohn C, Buhlmann CH, & Ryan MH (2025). Probing the pump: soil carbon dynamics, microbial carbon use efficiency and community composition in response to stoichiometrically-balanced compost and biochar. *Soil Biology & Biochemistry* **205** doi:10.1016/j.soilbio.2025.109770
132. Mo X, Shi S, Siddique K H M, Li Y, Zhang Z, and Zhang M (2025). Community interactions and functions drive bacteriome assembly in soil-plant continua of fragile estuarine wetland. *BMC Plant Biology* **25** doi:10.1186/s12870-025-07341-9
133. Moazzamnia E, Rezaei-Chiyaneh E, Dolatabadian A, Murariu OC, Sannino M, Caruso G, and Siddique KHM (2025). Effects of water stress and mulch type on linseed seed yield, physiological traits, and oil compounds. *Crops* **5:37** doi:10.3390/crops5030037
134. Mohamed HA, Rengel Z, Bolan N, Khan BA, Siddique KHM, and Solaiman ZM (2025). Adsorption of ammonium from anaerobic food waste digestate by pristine and modified eucalyptus biochar for nitrogen fertiliser use. *Journal of Soil Science and Plant Nutrition* **0(0)** doi:10.1007/s42729-025-02414-y
135. Mohamedikbal S, Al-Mamun H A, Bestry M S, Batley J, and Edwards D (2025). Integrating multi-omics and machine learning for disease resistance prediction in legumes. *Theoretical and Applied Genetics* **138** doi:10.1007/s00122-025-04948-2
136. Mohammed NH, Shikhmaidin M, Yong CSY, Ling KH, Martin GB (2025). Expression of progesterone receptor membrane component 1 PGRMC1 in follicular and luteal tissues in goats - Effect of short-term concentrate supplementation. *Tropical Animal Science Journal* **48(2)** 113 doi: 10.5398/tasj.2025.48.2.113
137. Mou Z, Hao Y, Chen X, Wang T, Turner BL, Kandeler E, Lambers H, Liu Z (2025). Climate and pedogenesis exert divergent controls on dissolved organic matter during long-term ecosystem development. *Catena* **254** doi: 10.1016/j.catena.2025.109004
138. Mou Z, Hao Y, Lambers H, Turner BL, Kandeler E, & Liu Z (2025). Unraveling the paradox: increased glomalin accumulation amid declining mycorrhizal biomass across a two-million-year dune chronosequence. *Plant and Soil* doi:10.1007/s11104-025-07391-w
139. Mukherjee S, Sharma S, Bolan S, Wang L, Berry TA, Wallis SL, Blanchon D, Hou D, Geoffroy VA, Siddique KHM, Bolan N (2025). A review on the bioweathering and bioremediation of asbestos containing waste materials in soils. *Soil Research* **63 4** doi: 10.1071/SR25013
140. Munir N, Sarwar Z, Hanif M, Siddiqui Z S, Siddique K H M, and Abideen Z (2025). Enhancing crop resilience and agricultural sustainability: synergistic interactions between phytohormones and nanoparticles. *Environmental Sustainability* doi:10.1007/s42398-025-00382-8
141. Murtini ES, Setyawan HY, Yuwono SS, Mamluhah L, Rahayu LF, Zhu M, & Okoye CO (2025). An investigation into the preparation and characteristics of carbonized rice straw for black food dye. *Cogent Food and Agriculture* **11** Article 2546987 doi:10.1080/23311932.2025.2546987
142. Niu Y, Wang L, Luo Z, Fudjoe S K, Palta J A, Li L, and Li S (2025). Effects of irrigation practices on potato yield and water productivity: a global meta-analysis. *Agronomy* **15(8)** doi:10.3390/agronomy15081942
143. Niu Y, Yang R, Li Z, Huo Z, Chang S, Tian E, Qin H, Cowling WA, Siddique KHM, Mason AS, Chen S, and Zou J (2025). Phenotypic advantages and improved genomic stability following selection in advanced selfing-generations of Brassica allohexaploids. *Journal of Genetics and Genomics* **0(0)** doi:10.1016/j.jgg.2025.03.004
144. Nizbat Z, Solaiman Z M, O'Connor J, Siddique K H M, and Bolan N (2025). Clay-based carbon stabilisation of organic amendments for enhanced soil organic carbon sequestration in agricultural soils. In Sparks D L (Ed.), *Advances in Agronomy* **193** 79–145 doi:10.1016/bs.agron.2025.05.005
145. Padhiar D, Kaur S, Jha UC, Prasad PVV, Sharma KD, Kumar S, Parida SK, Siddique KHM, and Nayyar H (2025). Differential resilience of chickpea's reproductive organs to cold stress across developmental stages: insights into antioxidant strategies for enhanced fertility. *Frontiers in Plant Science* **16** doi:10.3389/fpls.2025.1545187
146. Padhiar D, Kaur S, Rani A, Jha UC, Prasad PV, Sharma KD, Kumar S, Parida SK, Siddique KHM, and Nayyar H (2025). Deciphering the dynamics of enzymes associated with the synthesis of cryoprotectants during cold acclimation in contrasting chickpea genotypes. *Scientific Reports* **15**:19438 doi:10.1038/s41598-025-03211-4
147. Pan E, Wang D, Tan T, An J, Jin X, Zou H, Zhang Y, Yu N, and Siddique K H M (2025). Effect of organic amendments on soil organic carbon fractions, water retention, and mechanical properties in a Chinese Alfisol. *Soil and Tillage Research* **254** doi:10.1016/j.still.2025.106723
148. Pan X, Zhang M, Pu X, Dang P, Wang W, Huang T, Qin X, and Siddique K H M (2025). Film mulching improves yield and resource efficiency in corn-sunflower intercropping systems in the Guanzhong Plain of China. *Agronomy Journal* **117** e70163 doi:10.1002/agj2.70163
149. Pan Y, Wang D, Zou H, Tan T, Zhang Y, Yu N, An J, Jin X, and Siddique KHM (2025). Effect of organic amendments on soil organic carbon fractions, water retention, and mechanical properties in a Chinese Alfisol. *Soil & Tillage Research* doi:10.1016/j.still.2025.106723
150. Pandey A K, Barbetti M J, Tripathi K, Sonta P, Basandrai A, Basandrai A, Nair R M, and Lamichhane J R (2025). Powdery mildew epidemics in grain legumes and their management strategies. *Plant Pathology* **74(9)** doi:10.1111/ppa.70054
151. Pandey AK, Barbetti MJ, Kumar A, Gaulin E, Le May C, Pilet-Nayel M-L, You MP, and Lamichhane J-R (2025). Root disease complexes of arable crops: where do we stand and where should we go? Critical Reviews in Plant Sciences doi:10.1080/07352689.2025.2475671
152. Pang J, Li S, Mathesius U, Berger J, Zhang W, Sawant KD, Varshney RK, Siddique KHM, and Lambers H (2025). Wild Cicer species exhibit superior leaf photosynthetic phosphorus- and water-use efficiencies compared with cultivated chickpea under low-phosphorus conditions. *New Phytologist* **0(0)** doi:10.1111/nph.70185
153. Pang J, Tian Z, Zhang M, Wang Y, Qi T, Zhang Q, Liu E, Zhang W, Ren X, Jia Z, Siddique KHM, and Zhang P (2025). Enhancing carbon sequestration and greenhouse gas mitigation in semiarid farmland: The promising role of biochar application with biodegradable film mulching. *Journal of Integrative Agriculture* **24(2)** doi:10.1016/j.jia.2023.12.011

154. Pang J, Xu W, & Siddique KHM (2025). Harnessing the rhizosphere for sustainable agriculture: prospects for intercropping systems. *Plant and Soil* doi:10.1007/s11104-025-07983-6
155. Pannell D, Malcolm B (2025). A history of the Australasian Agricultural and Resource Economics Society. *Australian Journal of Agricultural and Resource Economics* doi:10.1111/1467-8489.70019
156. Pei B, Liu T, Xue Z, Cao J, Zhang Y, Yu M, Liu E, Xing J, Wang F, Ren X, Zhang Z (2025). Effects of biofertilizer on yield and quality of crops and properties of soil under field conditions in China: A meta-analysis. *Agriculture* **15** 10 doi:10.3390/agriculture15101066
157. Peng S, Zhang X, Sun L, Chai R, Zhang C, Chen X, Luo L, & Siddique KHM (2025). Matching phosphorus fertilizer types with soil type in rice cultivation optimizes yield, soil phosphorus availability, and phosphorus fertilizer use efficiency. *Agriculture* **15**(2):172 doi:10.3390/agriculture15020172
158. Peng Y, Chen A, Chen S, Chen Y (2025). Genotypic variability in root morphological traits in canola (*Brassica napus* L.) at the seedling stage. *Crops* **5**(2):18 doi:10.3390/crops5020018
159. Petereit J, Bayer P E, Tay Fernandez C G, Batley J, and Edwards D (2025). Changes of gene content in four crop species during domestication and breeding. *Agriculture Communications* **3**(1) doi:10.1016/j.agrcom.2025.100077
160. Pharmawati M, Wrasati L P, Wijaya I M A S, and Siddique K H M (2025). The potential of *Enhalus acoroides* as a biostimulant to enhance maize growth and drought tolerance. *BIOTROPICA* **32**(2) 242-253 doi:10.1159/btb.2025.32.2.2487
161. Ping X, Yan M, Wang J, Ye Q, Zhang T, Hu X, Chen S, Li J, Liu L (2025). A Golden2-like transcription factor regulates *Brassica napus* seed vigor after artificial aging. *Theoretical and Applied Genetics* **138** **5** doi:10.1007/s00122-025-04884-1
162. Pratap A, Taylor NL, Pal M, Chinnusamy V, and Siddique KHM (2025). Heat tolerance mechanisms in bread wheat: Insights from flag leaves and spike tissues. *Plant Stress* **16** doi:10.1016/j.stress.2025.100876
163. Priya M, Farooq M, Siddique KHM (2025). Enhancing tolerance to combined heat and drought stress in cool-season grain legumes: Mechanisms, genetic insights, and future directions. *Plant, Cell & Environment*, **2025** doi:10.1111/pce.15382
164. Prusty A K, Ravisankar N, Kaur J, Joshi H, Rani M, Lopez Ridau S, Groote J C J, Jat M L, Barba-Escoto L, Shamima M, Ansari M A, Paramesha V, Siddique K H M, Kashyap P, Singh R, Raghavendra K J, Swarnam T P, Panwar A S, and Kumar S (2025). Tailored framework for sustainable intensification of marginal and small farms using farm typology to strengthen farm income. *Environmental and Sustainability Indicators* **27** 100847 doi:10.1016/j.indic.2025.100847
165. Puga G, & Anderson K (2025). Statistical methods in grape and wine research for quantifying the impact of climate change. *OENO One* **59**(1) doi:10.20870/oeno-one.2025.59.1.8114
166. Quinones J, Huaquian R, Diaz R, Nunez IP, Cortes M, Martinez A, Sepulveda G, Velasquez L, Cancino D, Paz E, Sepulveda N (2025). Effect of dietary supplementation of *Durvillaea Antarctica* meal on production and meat quality traits of lambs. *Animals* **15**(2) doi:10.3390/ani15020206
167. Raut D, Gadakh S, Kute N, Blesseena A, Gangarao NVPR, Siddique KHM, Rane J (2025). Identifying chickpea (*Cicer arietinum* L.) genotypes rich in ascorbic acid as a source of drought tolerance. *Scientific Reports* **15** **6019** doi:10.1038/s41598-024-76394-x
168. Rawat N, Sharma Y, Wang Y, Chen ZH, Siddique KHM, Shabala S, Pareek A, and Singla-Pareek S (2025). Refining osmosensing mechanisms for crop resilience: insights from glycophytes and halophytes. *Plant, Cell & Environment* **1-15** doi:10.1111/pce.15669
169. Raza A, Anas M, Bhardwaj S, Mir RA, Charagh S, Elahi M, Zhang X, Mir RR, Weckwerth W, Fernie AR, Siddique KHM, Hu Z, Varshney RK (2025). Harnessing metabolomics for enhanced crop drought tolerance. *The Crop Journal* doi:10.1016/j.cj.2025.01.001
170. Saha S, Alam M J, Al Abbasi A A, Begum I A, Rola-Rubzen M F, and McKenzie A M (2025). Impact of human capital and remittances on agricultural productivity in Bangladesh. *Journal of Agriculture and Food Research* **22** doi:10.1016/j.jafr.2025.102073
171. Saha S, Alam MJ, Al Abbasi AA, Begum IA, Parikh P, Rola-Rubzen MF (2025). The effect of rural land mortgaging on rural transformation at the regional level in Bangladesh. *Land Degradation & Development* doi:10.1002/ldr.5476
172. Salami M, Tan H, Thomas W J W, Batley J, and Heidari B (2025). Genome wide association study (GWAS) combined with transcriptome analysis reveals the key genes underlying the production of seed oil, mono and poly unsaturated fatty acids in *Brassica napus*. *Industrial Crops and Products* **231** doi:10.1016/j.indcrop.2025.121205
173. Samuditha S, Fernandez AB, Siddique KHM, Biswas J, & Vithanage M (2025). Exploring Biochar Impacts Through Omics Sciences: Enhancing Rhizobiome Understanding. *J Soil Sci Plant Nutr* **25** 8522-8544 doi:10.1007/s42729-025-02650-2
174. Sarfaraz Q, Sharma R, Drescher GL, Zafar M, Shafi MI, Anderson GC, da Silva LS, & Solaiman ZM (2025). Interactive effects of biochar and ammonium fertilizer on wheat yield, soil acidity and their residual effect on soybean under no-tillage conditions. *AIMS Agriculture and Food* **10** 819-838 doi:10.3934/agrfood.2025043
175. Sharma P, Lakra N, Luhach A, Zaid A, and Siddique KHM (2025). Putrescine attenuates heat stress by modulating membrane stability, antioxidant activity, and gaseous exchange in *Brassica juncea* L. *Plant Science* **359**:112609 doi:10.1016/j.plantsci.2025.112609
176. Sharma S, Bolan S, Mukherjee S, Guilherme L R G, Viana D G, Ferreira A D, Myrvang M B, Almås Å R, Gjengedal E L F, Cappuyns V, Guerra M B B, de Oliveira C, Lamb D, Siddique K H M, and Bolan N (2025). Barium distribution, dynamics and fate in terrestrial and aquatic environments. *Environmental Research* **287** doi:10.1016/j.envres.2025.123059
177. Sharma S, Bolan S, Mukherjee S, Petruzzelli G, Pedron F, Franchi E, Fonseka W, Wijesekara H, Wang L, Hou D, Siddique KHM, and Bolan N (2025). Role of organic and biochar amendments on enhanced bioremediation of soils contaminated with persistent organic pollutants (POPs). *Current Pollution Reports* **11**:33 doi:10.1007/s40726-025-00361-x
178. Sharma S, Bolan S, Yang X, Mukherjee S, Zhou P, White JC, Zuverza-Mena N, Zhang Z, Chen J, Xu Q, Wei X, Tao T, Lyu S, Sandanayake S, Vithanage M, and Bolan N (2025). Titanium: metal of the future or an emerging environmental contaminant? *Explora: Environment and Resource* doi:10.36922/EER025130027
179. Sharma S, Mukherjee S, Bolan S, de Figueiredo C, Fachini J, Chang SX, Palansooriya KN, Zhou P, Hou D, Kaya C, Siddique KHM, and Bolan N (2025). Biochar as a potential nutrient carrier for agricultural applications. *Current Pollution Reports* **11** doi:10.1007/s40726-025-00349-7
180. Shen Q, Xiao J, Wang L, Feng J, Chen Y, Zhu B, Li H, Lambers H (2025). Maize shows intraspecific facilitation under phosphorus deficiency but competition under nitrogen deficiency when grown under increased plant densities in alkaline soil. *Plant and Soil* doi:10.1007/s11104-024-07188-3
181. Shi J, Xu M, He X, Zhou H, and Li J (2025). Climate, soil and management factors drive the quantitative relationships between soil fertility and spring maize water productivity in northern China. *Agricultural Water Management* **316** doi:10.1016/j.agwat.2025.109599
182. Shi M, Liu C, Wang X, Guo Z, Wang Z, Wang R, Hui X, Lin J, Siddique KHM, & Wang Z (2025). High phosphorus fertilization increases manganese accumulation in wheat: absorption and transport mechanisms. *Journal of Agricultural and Food Chemistry* doi:10.1021/acs.jafc.5c02931
183. Shi Q, Ma M, Bai C, Liu Y, Sun Z, Pang J, Salam SA, Zhang S, Liu H, Zhang F, Siddique KHM, and Lambers H (2025). Optimising peanut growth: Exogenous calcium enhances photosynthesis in phosphorus-limited environments. *Plant, Cell & Environment* **0**(0) doi:10.1111/pce.15591
184. Song H, Niu T, Dong J, Hou Q, Feng Y, Liu H, Liu X, Liu A, Xu L, & Zhou W (2025). Tandem duplicate genes preferentially contribute to the resistance of abiotic stress in sunflowers. *Industrial Crops and Products* **230** doi:10.1016/j.indcrop.2025.121129
185. Su Z, Gao S, Hu H, Shabala S, Zhou M, Liu C, and Zheng Z (2025). A major locus conferring both *Fusarium* crown rot resistance and drought tolerance in barley (*Hordeum vulgare* L.). *Plant Breeding* **144**(5) doi:10.1111/pbr.13289

186. Suazo-Hernández J, Cáceres-Jensen L, Pesenti H, Corradini F, Mora M L, Bolan N, Cornejo P, and Sarkar B (2025). Microplastics influence phosphate adsorption in volcanic ash soil. *J Soil Sci Plant Nutr* **25** doi:10.1007/s42729-025-02472-2
187. Sun C, Wang R, Li J, Li X, Song B, Edwards D, & Wu J (2025). Pan-transcriptome analysis provides insights into resistance and fruit quality breeding of pear (*Pyrus pyrifolia*). *Journal of Integrative Agriculture* **24**(5) doi:10.1016/j.jia.2024.11.026
188. Sun Y, Hu L, Amas JC, Thomas WJW, Wang L, Wang X, Wang W, Qu G, Shen X, Ji R, Batley J, Fan C, Wang Y (2025). BrRCO promotes leaf lobe formation by repressing BrACP5 expression in Brassica rapa. *Horticulture Research* **12** **5** doi: 10.1093/hr/huahf084
189. Sun Y, Yang X, Nan T, Du T, Kang S, Siddique K H M, and Butterbach-Bahl K (2025). Distinct soil nutrient availability drives variation in the microbial community and functions in wheat and maize rhizosphere under diversified crop rotations. *Plant and Soil* doi:10.1007/s11104-025-07956-9
190. Swella G, Ward P, Siddique KHM, and Flower KC (2025). Crop residue orientation influences soil water and wheat growth under rainfed Mediterranean conditions. *Agronomy* **15**:1285. doi:10.3390/agronomy15061285
191. Thomas W J W, You M P, Amas J C, Edwards D, Banga S S, Barbeti M J, and Batley J (2025). First report of genomic regions associated with white leaf spot resistance in Brassica napus. *Plant Pathology* **74**(9) doi:10.1111/ppa.70059
192. Uz Zaman MS, Hasan MM, Luna LN, Iqbal MS, Malik AI, Hossain MA (2025). Contrasting responses to waterlogging in emergence, growth, and yield of mungbean and blackgram. *Plant and Soil* doi:10.1007/s11104-024-07199-0
193. Veresoglou S D, Lambers H (2025). Does the mycorrhizal mediation hypothesis capture biogeographical patterns in plant-soil feedback? The case of conspecific negative density dependencies. *Soil Ecology Letters* **7** **2** doi: 10.1007/s42832-025-0293-3
194. Vikraman V K, and Manali S (2025). Pyrolysis of post-consumption food waste with insights into kinetics, energy demand and products analysis. *Biomass and Bioenergy* **201** doi:10.1016/j.biombioe.2025.108152
195. Vuong T D, He G, Hu H, Valliyodan B, Lee D, Bayer P E, Schapaugh W T, Hessel R, Edwards D, and Nguyen H T (2025). Identification of new genomic loci for seed protein and oil content in the soybean pangenome using genome wide association and haplotype analyses. *Theoretical and Applied Genetics* **138**(9) doi:10.1007/s00122-025-05020-9
196. Wang C, Fan J, Zeng Y, Li H, Bu C, Chen X, Wang H, Mo Q, and Zhang Z (2025). Key factors for the rapid cultivation of lithophytic moss crusts and preliminary trials in the ecological restoration of rocky slopes. *Land Degradation & Development* **0**:1-12 doi:10.1002/ldr.70059
197. Wang C, Zhang C, Xie Z, Wang D, Meng Y, Sun Y, Chen Y, Li Z, Kang Y, Guo Y (2025). Engineered silicate-solubilizing bacterial community alleviates nutrient stress in field-grown maize by enhancing silicon uptake and optimizing rhizosphere microecology. *Field Crops Research* **326** doi: 10.1016/j.fcr.2025.109827
198. Wang H, Sun J, Ren H, Zhao B, Li Y, Zhang Z, Ren B, Khan A, Zhang J, Chen Y, & Liu P (2025). Increased hormone activity promotes silk development and heat tolerance during the floret differentiation stage in maize. *Crop Journal* **13**(2) doi:10.1016/j.cj.2024.12.019
199. Wang J, Turner NC, and He H (2025). Calibration is required for use of electromagnetic soil moisture sensors to accurately measure the water content of tree stems and sawdust. *Plant and Soil* **0**(0) doi:10.1007/s11104-025-07475-7
200. Wang L, Garland G M, Ge T, Guo S, Kebede E A, He C, Hijri M, Plaza-Bonilla D, Stringer L C, Davis K F, Lee S-J, Feng S, Wang L, Wei Z, Cao H, Wang Z, Xu J, Siddique K H M, Gan G Y, & Zhao M (2025). Integrated strategies for enhancing agrifood productivity, lowering greenhouse gas emissions, and improving soil health. *The Innovation*, doi:10.1016/j.xiin.2025.101006
201. Wang L, Guo S, Hijri M, Farooq M, Rehman A, Ge T, Feng S, Wei Z, Zhang J, Zhao C, Kang S, Siddique KHM, Jin Z, Zhao M, Gan GY (2025). Enhancing carbon restoration and ecosystem resilience in global drylands via water-to-carbon biotransformation strategies. *Communications Earth & Environment* **6** doi:10.1038/s43247-025-02874-1
202. Wang L, Guo S, Zhang J, Field K J, Delgado Baquerizo M, de Souza T A F, Lee S J, Hijri M, Shang X, Sun D, Cao H, Feng S, Wang L, Ji H, Van der Heijden M, Siddique K H M, and Gan G Y (2025). Arbuscular mycorrhizal networks—a climate smart blueprint for agriculture. *Plant Communications* **6**(11) doi:10.1016/j.xplc.2025.101526
203. Wang L, Li L, Xie J, Luo Z, Fudjoe SK, Palta JA, & Li S (2025). Trade-offs among yield, water productivity, water footprint, and economic benefits for wheat production under conservation tillage: a long-term field experiment approach. *Agricultural Water Management* **312** doi:10.1016/j.agwat.2025.109435
204. Wang L, Li Y, Biswas A, Zhao Y, Niu B, and Siddique KHM (2025). Assessing climate change and human impacts on runoff and hydrological droughts in the Yellow River Basin using a machine learning-enhanced hydrological modeling approach. *Journal of Environmental Management* **380** doi:10.1016/j.jenvman.2025.125091
205. Wang L, Liao D, Rengel Z, & Shen J (2025). Soil-plant-microbe interactions in the rhizosphere: incremental amplification induced by localized fertilization. *Frontiers of Agricultural Science and Engineering* **12**(1) doi:10.15302/J-FASE-2024575
206. Wang L, Song S, Li H, Liu Y, Xu L, Li H, You C, Liu S, Xu H, Tan B, Xu Z, Zhang L, Lambers H, & Godbold D (2025). Soil phosphorus dynamics and its correlation with ectomycorrhizal fungi following forest conversion in subtropical conifer (*Picea asperata*) forests. *European Journal of Soil Biology* **124** doi:10.1016/j.ejsobi.2025.103712
207. Wang S, Li Y, Li T, Lu W, Qi X, Xie X, Sa R, Guo T, Pulatov A, Javlonbek I, Tang D W S, & Siddique K H M (2025). Regional maize suitability based on soil water and salt content inversion by integrating machine and transfer learnings in Xinjiang. *Soil & Tillage Research*, doi:10.1016/j.still.2025.106740
208. Wang X, Wu X, Hua Y, Li Y, Ma L, Gong Y, Zhu W, Xu S, Xue J, Qin X, Siddique KHM (2025). Optimizing maize production in the Guanzhong Region: An evaluation of density tolerance, yield, and mechanical harvesting characteristics in different maize varieties. *European Journal of Agronomy*, **164**, 127500 doi: 10.1016/j.eja.2025.127500
209. Wang X, Yang Q, Asad M S, Yan Z, Chen X, Zhao X, Liu E, Jia Z, Siddique K H M, and Ren X (2025). Coupling no-tillage with bio-organic fertilizer strategies to regulate soil quality and microbial communities, without compromising crop yield under rainfed conditions on the Loess Plateau, China. *Plant and Soil* doi:10.1007/s11104-025-07783-y
210. Wang Y, Ji Y, Ma L, Elena M, Assiya A, Ding R, Jia Z, Siddique KHM, Liu E, He J, Zhang W, Zhang P (2025). Evaluate the impacts of different straw returning rates on soil quality and field environmental sustainability of film mulching or non-mulching farmland in semiarid region. *Environmental Research* **285**(3) doi:10.1016/j.envres.2025.122483
211. Whittall S, & Beatty T (2025). Postharvest losses from temperature during transit: Evidence from a million truckloads. *American Journal of Agricultural Economics* doi:10.1111/ajae.70019
212. Wiese R, Ryan M, Nichols P, Moss W, Wintle B, Zago Y, Hunt L, Hamblin A, and Guzzomi A (2025). Swathing subterranean clover (*Trifolium subterraneum*) does not suck: a promising alternative to vacuum seed harvesting. *Crop & Pasture Science* **76** doi:10.1071/CP24357
213. Wilkening JV, Dawson TE, Thompson SE (2025). Mind the data gap: Using a multi-measurement synthesis for identifying the challenges and opportunities in studying plant drought response and recovery. *Plant Cell and Environment* doi:10.1111/pce.15349
214. Wu Q, Yang L, Chen Y, Liang H, Liu M, Chen D, Shen P (2025). Acid phosphatase-driven advancements in peanut growth and microbial community dynamics in phosphorus-limited soils. *Journal of Soil Science and Plant Nutrition* doi:10.1007/s42729-024-02114-z

215. Wu Z, Zhang Y, Fan Y, Wang C, Li B, Rengel Z, Shen J, le Cadre E, Whalen J, & Tang X (2025). Decadal manure substitution reshapes microbial communities to drive plant and microbial carbon accumulation in soil carbon fractions. *Geoderma* **463** Article 117581 doi:10.1016/j.geoderma.2025.117581
216. Xiang Y, Luo J, Liu Y, Luo Y, Bolan N, Fan J, Shurpali NJ, Bhattarai H, and Siddique KHM (2025). Enhancing Soil Physicochemical Properties and Fruit Production of Rosa roxburghii With Biochar-Based Fertilizer in Karst Agricultural Systems. *Food and Energy Security*, **14**(5) e70138. doi.org/10.1002/fes3.70138
217. Xie L, Li Y, Zhang Z, Siddique KHM, and Song X (2025). Exploring the combined effects of drought and drought-flood abrupt alternation on vegetation using interpretable machine learning model and r-vine copula function. *Agricultural and Forest Meteorology* **370** doi:10.1016/j.agrformet.2025.110568
218. Xie L, Yang Y, Ma J, Deng J, Gille CE, Zhang Z, Liu M, Robson TM, & Wang QW (2025). Variation in seedling growth, root exudates and rhizosphere microbial communities of two temperate tree species under fluctuating light and extreme drought. *Plant and Soil* **517** 487–507 doi:10.1007/s11104-025-07878-6
219. Xu C, Dang P, Haegeman B, Huang T, Han X, Zhang M, Wang S, Qin X, and Siddique KHM (2025). Winter wheat cultivar improvement impacts rare bacterial communities in the rhizosphere more than abundant bacterial communities. *Applied Soil Ecology* **210** doi:10.1016/j.apsoil.2025.106071
220. Yang J, Wang R, Xu J, Guo Z, Liu C, Chen Y, Shi M, & Wang Z (2025). Mitigating phosphorus-zinc antagonism in calcareous soils through the interaction of high-zinc wheat and the rhizospheric microbiome. *Field Crops Research* **322** doi:10.1016/j.fcr.2025.109762
221. Yang N, Zhang M, Pan X, Dang P, Wang S, Han X, Wang X, Zhang C, Meng M, Wang W, Zhang X, Siddique KHM, Li Y, and Qin X (2025). Characteristics of changes to POC and MAOC after straw returning in China: a meta-analysis. *Land Degradation & Development* **0:1–13** doi:10.1002/ldr.5696
222. Yang R, Harrison MT, Yang Y, Wang C, Shabala S, Huang M, Zhao C, Zhou M, Sun C, & Liu K (2025). Pre-harvest sprouting in cereals: Global incidence, impacts and mitigation strategies. *Field Crops Research* **333** Article 110111 doi:10.1016/j.fcr.2025.110111
223. Yang S, Zhang H, Jin Y, Turner NC, Pang J, Chen Y, and He J (2025). Coordination of abscisic acid and hydraulic signals in stomatal closure and yield of soybean genotypes with varying isohydry under different water conditions. *Agricultural Water Management* **313** doi:10.1016/j.agwat.2025.109495
224. Yang X, Yu R, Yu G, Bai Y, Li M, Liu Z, Qu S, Miao P, Ma H, Zhang T, & Jia Y (2025). Revolutionizing salinized farmland: how salt-controlled irrigation transforms microbial diversity and soil organic matter in a salt-alkali soil. *Agronomy* **15**(4) doi:10.3390/agronomy15040956
225. Ye D, Lin Y, Liu T, Zhang X, Tang Y, Wang K, Huang H, Yu H, Wang Y, He X, & Li T (2025). Soil microbial community harboring key genes drives rhizosphere phosphorus mobilization of phosphorus-accumulating *Polygonum hydropiper*. *Applied Soil Ecology* **213** Article 106314 doi:10.1016/j.apsoil.2025.106314
226. Yilma S, Bekele B, Van Leur J, You MP, Kemal S-A, Giblot-Ducray D, Hill K, Selvaraji T, Lencho A, Driba L, & Barbeti MJ (2025). Defining soilborne pathogen complexes provides a new foundation for the effective management of faba bean root diseases in Ethiopia. *Pathogens* **14**:695 doi:10.3390/pathogens14070695
227. Yun P, Solis C A, Shahzad B, Shabala L, Zhou M, Venkataraman G, Chen Z H, and Shabala S (2025). Chloride dependent plasma membrane hyperpolarization confers superior salinity tissue tolerance in wild rice (*Oryza coarctata*). *Crop Journal* **13**(3) doi:10.1016/j.cj.2025.04.002
228. Zaalberg R M, Andersen L B, Hansen L S, Gebreyesus G, Henryon M, Jensen K, and Nielsen H M (2025). Short communication: substantial heritability of larval size in the black soldier fly reveals potential for selective breeding. *Animal* **19**(6) doi:10.1016/j.animal.2025.101534
229. Zakaria N, Han H, Khalil Y, Ashworth M, Yu Q, Flower KC (2025). EPSPS target site mechanisms confer glyphosate resistance in *Arctotheca calendula*. *Pest Management Science* **81**(6) doi: 10.1002/ps.8690
230. Zarezadeh S, Zheng Y, Jenkins S N, Mercer G D, Moheimani N R, Singh P, and Mickan B S (2025). Sustainable soil management in agriculture under drought stress: utilising waste-derived organic soil amendments and beneficial impacts on soil bacterial processes. *Applied Soil Ecology* **206** doi:10.1016/j.apsoil.2025.105870
231. Zeng Y, Liu M, Qian H, Zhao H, Fang Y, Yu Q, Bai L, Pan L (2025). Investigating non-target site resistance to pyroxulam in a glyphosate-resistant *Lolium rigidum* population. *Pest Management Science* doi:10.1002/ps.8636
232. Zhang B, Fang H, Zhang G, Li S, Wu S, and Siddique KHM (2025). Integrating multi-model frameworks to unravel the spatiotemporal dynamics of flash floods in the Tianshan Mountain, China. *Ecological Indicators* **172** doi:10.1016/j.ecolind.2025.113259
233. Zhang H, Li S, Wang S, Shi B, Wang X, Pang J, Sun H, Tian P, Ma H, and Wu Z (2025). Silicon enhances yield in dry-cultivated rice/soybean intercropping systems by altering root morphology and distribution. *Food and Energy Security (online first)* doi:10.1002/fes3.70111
234. Zhang K, Bai J, Wang J, Guo J, Sun H, Liu J, Siddique K H M, and Mao H (2025). Polyethylene microplastics modulate zinc oxide nanoparticle toxicity effects on nutrient dynamics and rhizosphere bacterial community in pakchoi. *Applied Soil Ecology* **216** doi:10.1016/j.apsoil.2025.106505
235. Zhang L, Xu C, Han H, Askew S, Ervin E, Yu Q, and Wang K (2025). What is new for the mechanisms of plant resistance to paraquat after decades of research? *Agriculture (Switzerland)* **15**(12) doi:10.3390/agriculture15121288
236. Zhang M, Yang N, Han X, Lal R, Huang T, Dang P, Xue J, Qin X, and Siddique KHM (2025). Effects of straw returning depth on soil organic carbon sequestration and crop yield in China: A meta-analysis. *Agriculture, Ecosystems and Environment* **393**:109799. doi:10.1016/j.agee.2025.109799
237. Zhang M, Zhao X, Han X, Chen Y, Dang P, Xue J, Qin X, and Siddique KHM (2025). Optimizing planting density for enhanced maize yield and resource use efficiency in China: a meta-analysis. *Agronomy for Sustainable Development* **45**:29 doi:10.1007/s13593-025-01027-0
238. Zhang N, Xing J, Wei L, Liu C, Zhao W, Liu Z, Wang Y, Liu E, Ren X, Jia Z, Wei T, Siddique KHM, Zhang P (2025). The potential of biochar to mitigate soil acidification: a global meta-analysis. *Biochar* **5** doi:10.1007/s42773-025-00451-5
239. Zhang S, Ren T, Fang Y, Zhao J, Zhu J, Cong W-f, Lambers H, Lu J (2025). Enhancing soil labile organic matter through oilseed rape-rice rotation and straw returning in paddy-upland systems. *Plant and Soil* doi: 10.1007/s11104-025-07517-0
240. Zhang W, He J, Zhang M, Nugmanov A, Liu E, Ren X, Jia Z, Siddique K H M, Wang Y, and Zhang P (2025). Optimal straw return rate to ensure synergistic improvement of maize productivity and soil nutrients: a case study in semiarid region. *Land Degradation & Development* doi:10.1002/ldr.70286
241. Zhang W, Ju M, Wu S, Bu C, Fan J, Li X, Wei Y, Pang J, & Siddique KHM (2025). Interactive effects of carbon and nitrogen fixation in two biocrust types in the Mu Us Sandland. *Catena* doi:10.1016/j.catena.2025.109305
242. Zhang W, Pang J, Qi J, Lu Y, Liu J, Yu M, Li H, Wang E, Lambers H (2025). Biochar's dual impact on soil acidity management and crop yield enhancement in acidic soils: a meta-analysis. *Plant and Soil*. doi: 10.1007/s11104-025-07490-8
243. Zhang X, Xu L, Wang Y, He M, Xin R, Yang Z, Chu W, Ma Y, Chen Y, Wang L, Liu L (2025). RsWOX13 promotes taproot development by activating cell division and expansion and sucrose metabolism in radish. *Plant Physiology and Biochemistry* **220** doi:10.1016/j.plaphy.2024.109449
244. Zhang Y, Zhu W, Luo L, Lambers H, Zhang C (2025). The yield and phosphorus content of maize intercropped with faba bean are enhanced by belowground interspecies interactions at low phosphorus input and by aboveground interactions at high phosphorus input. *Plant and Soil* doi:10.1007/s11104-024-07168-7
245. Zhang Z, Wang Z, Ye S, Wang S (2025). Dynamic changes of soil aggregate-associated phosphorus adsorption-desorption characteristics in a chronosequence of Chinese fir plantations. *Soil & Tillage Research* **249** doi: 10.1016/j.still.2025.106479

246. Zhao D, de Voil P, Sadras VO, Palta JA, Rodriguez D (2025). The plasticity of root traits and their effects on crop yield and yield stability. *Plant and Soil* doi:10.1007/s11104-024-07185-6
247. Zhao L, Zhang Z, & He H (2025). Effects of phosphate fertilization and intercropping on plant growth, nitrogen and phosphorus uptake of millet and soybean across three soil types. *Journal of Soils and Sediments* **25**(4) doi:10.1007/s11368-025-04003-z
248. Zhao S, Zhang Q, Chen X, Huang Q, Li H, and Siddique K H M (2025). Biochar counteracts the negative effects of microplastics on physiological and biochemical characteristics and leaf metabolism in Zea mays L. *Journal of Hazardous Materials* **496** 139355 doi:10.1016/j.jhazmat.2025.139355
249. Zhong H, Zhou J, Turner BL, Watson FT, & Lambers H (2025). Soil phosphorus transformations along two long-term chronosequences with contrasting climate in south-western Australia. *Plant and Soil* doi:10.1007/s11104-025-07362-1
250. Zhou L, Zhang H, Ma L, Siddique KHM, Feng H (2025). Simulating plastic mulching effects on the soil water balance and maize yields using the modified RZ-SHAW model. *Field Crops Research*, **322** 109712 doi: 10.1016/j.fcr.2024.109712
251. Zhou Y, Li Y, Pan L, Lambers H, & Wang X (2025). Intercropping promotes maize growth by enhancing accumulation of specific metabolites in the rhizosphere and synergistic interaction between arbuscular mycorrhizal fungi and *Bacillus*. *Plant and Soil* doi:10.1007/s11104-025-07530-3
252. Zhu J, Niu W, Du Y, Zhang Z, Yang R, Siddique K H M, and Sun J (2025). Aerated drip irrigation changes soil microbial functional potential and enhances soil organic carbon content. *Pedosphere* **35**(3) doi:10.1016/j.pedsph.2024.03.002
253. Zhu JJ, Niu WQ, Du YD, Zhang ZH, Yang RY, Siddique KHM, and Sun J (2025). Aerated drip irrigation changes soil microbial functional potential and enhances soil organic carbon content. *Pedosphere* **35**(3):462–474 doi:10.1016/j.pedsph.2024.03.002.

Book chapters

1. Bandehagh A, Dehghanian Z, and Taylor NL (2025). Phytohormones in waterlogging and flooding resilience of oilseed crops. In: Latef A A H A (ed.), *Oilseed Crops Under Abiotic Stress: Mitigation Strategies and Future Perspectives*. Sustainability Sciences in Asia and Africa. Springer Singapore. doi:10.1007/978-981-96-8346-8_11
2. Bolan N, Srinivasarao C, Rocco C, Bolan S, Mansoor S, Wani OA, 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, Siddique KHM (2025). Zinc in soil-crop-animal-human health continuum. *Advances in Agronomy* **189** doi:10.1016/bs.agron.2024.09.004
3. Jeddi K, Abbes K, Lassoued M, Jeddi K, Hessini K, Siddique KHM, Chermiti B (2025). Attractiveness of Mediterranean native plants to arthropod natural enemies and herbivores. *Arthropod-Plant Interactions* **19** doi:10.1007/s11829-025-10204-7
4. Kumari S, Haroon H, Sahoo R N, Siddique KHM, and Khan MIR (2025). Interactions between wheat root system and salt stress environments: glimpses of omics interventions. Taylor & Francis Group
5. Noorka IR, Qureshi MT, Khan ZI, Siddique KHM, Heslop Harrison JS (2025). Biofortification of food grains in relation to food security. In: Shah AN, editor. *Crop Biofortification: Biotechnological Approaches for Achieving Nutritional Security under Changing Climate*, 1st ed. John Wiley & Sons Ltd
6. Wang Y, Ji Y, Ma J, Elena M, Assiya A, Ding R, Jia Z, Siddique KHM, Liu E, He J, Zhang W, Zhang P (2025). Evaluate the impacts of different straw returning rates on soil quality and field environmental sustainability of film mulching or non-mulching farmland in semiarid region. *Environmental Research* **285**(3) doi:10.1016/j.envres.2025.122483

Acronyms

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences	Cd	Soil cadmium	EC	Electrical conductivity
ACIAR	Australian Centre for International Agricultural Research	CDI	Clostridioides difficile infection	eFP	Electronic Fluorescent Pictographs
AcSIR	Academy of Scientific & Innovative Research	CEC	Cation exchange capacity	EIAR	Ethiopian Institute of Agricultural Research
ACT	Australian Capital Territory	CEI:AgER	The Centre for Engineering Innovation: Agriculture & Ecological Restoration	EWP	Engineered wood product
AEGIC	Australian Export Grains Innovation Centre	CGIAR	Consultative Group on International Agricultural Research	FA	Formic acid
AGBU	Animal Genetics and Breeding Unit	CIBER	Centre for Integrative Bee Research	FAO	Food and Agriculture Organization
AGT	Australian Grain Technologies	CK	Conventional management	FOGO	Food organics and garden organics
AHRI	Australian Herbicide Resistance Initiative	CKT	Cooking time	G	Genotype
AIA	Ag Institute of Australia	CMD	Collaborative Market Driving	GC-MS	Gas Chromatography–Mass Spectrometry
Al	Aluminium	CME	Co-operative and Mutual Enterprise	GGA	Grower Group Alliance
ALBA	Annual Legume Breeding Australia	CMS	Cytoplasmic male sterility	GHG	Global greenhouse gas
Alliance-CIAT	Alliance of Bioversity International and International Center for Tropical Agriculture	COGGO	Council of Grain Growers Organisation	GM	Genetically modified
AM	Arbuscular mycorrhizal	CPEC	Cripps Pink	GPRI	Gascoyne Pilbara Rangelands Initiative
AMF	Arbuscular mycorrhizal fungi	CRC	Cooperative Research in Australia	GPS	Global Positioning System
AMR	Antimicrobial resistance	CRC - SAAFE	Cooperative Research in Australia for Solving Antimicrobial Resistance in Agribusiness Food and Environment	GRDC	Grains Research and Development Corporation
ANABP	Australian National Apple Breeding Program	CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats	GREMO	Global Research Institute for Mobility in Society
ANFF	Australian National Fabrication Facility	CRM	Customer Relationship Management	Gs	Stomatal conductance
ANU	Australian National University	CRY1	Cryptochrome 1	GSH	Glutathione
APLV	Andean potato latent	CS	Climate-Smart	GSI	Gametophytic self-incompatibility
APMMV	Andean mild mosaic virus	CS	Cold-sensitive	GWAS	Genome-wide association studies
APPN	Australian Plant Phenomics Network	CSAP	Climate-Smart Agricultural Practices	GY	Grain Yield
APVMA	Australian Pesticides and Veterinary Medicines Authority	CSC	Chinese Scholarship Council	HDR	High degree by research
ARB	Antibiotic resistant bacteria	CSIRO	Commonwealth Scientific and Industrial Research Organization	HP	High phosphorus
ARC	Australian Research Council	CT	Cold-tolerant	HPA	Hop Products Australia
ARG	Antibiotic resistance gene	DAF	Department of Agriculture and Fisheries, Australia	HRM	Heat Ratio Method
AsA	Ascorbate	DAFF	Department of Agriculture, Fisheries and Forestry, Australia	HS	Heat stress
ASSD	Ammonium sulphate solid digestate	DAPs	Differentially abundant proteins	IAB	Institute Advisory Board
AWI	Australian Wool Innovation	DBM	Diamondback moth	ICAR	Indian Agricultural Research Institute
BA	Bifidobacterium adolescentis	DCD	Dicyandiamide	ICARDA	International Center for Agricultural Research in the Dry Areas
BD	Bulk density	DCE	Discrete Choice Experiment	IMB	Institute Management Board
BHP	Broken Hill Proprietary (company)	DCI	Dominance Candidate Index	IOA	The UWA Institute of Agriculture
BICWA	Beekeeping Industry Council of Western Australia	DEFRA	Department of Environment Food and Rural Affairs, United Kingdom	IPM	Integrated pest management
BPFS	Best Practice Farming Systems	DEGs	Differentially expressed genes	ISABU	Institut des Sciences Agronomiques du Burundi
BR	Biochar	DETF	Days from emergence to flowering	ISS	Industrial steel slag
C	Carbon	DH	Doubled Haploid	JA	Jasmonic acid
Ca	Calcium	DISER	Department of Industry, Science, Energy and Resources, Australia	K	Potassium
CA	Conservation agriculture	DM	Degradable film mulching	KALRO	Kenya Agricultural and Livestock Research Organization
CAAS	Chinese Academy of Agricultural Sciences	DOC	Dissolved organic carbon	KASP	Kompetitive Allele-Specific PCR
CAS	Chinese Academy of Sciences	DOST-SEI	Philippine's Department of Science and Technology Science Education Institute Foreign Graduate Scholarship	KPCA	Kimberley Pilbara Cattlemen's Association
CAUL	Council of Australasian University Librarians	dpi	Days post infection	LC	Liquid chromatography
CAZymes	Carbohydrate-active enzymes	DPI	Department of Primary Industries	LinCCC	Lin's concordance correlation coefficient
CBH	Co-operative Bulk Handling (company)	DPIRD	Department of Primary Industries and Regional Development, Western Australia	LP	Low phosphorus
CCs	Cover crops			M	Magnesium
				MALFF	Timor-Leste's Ministry of Agriculture, Livestock, Fisheries and Forestry

MAOC	Mineral-associated organic carbon	PRE	Phosphorus remobilization efficiency	TILLING	Targeting Induced Local Lesions in Genomes
MBC	Microbial biomass carbon	PUE	Productivity per unit P uptake	TM	Transparent film mulching
MeJA	Melatonin and methyl jasmonates	PUE	Puse efficiency	TM-CCs	Transmembrane-coiled coil proteins
MERiL	Methane Emissions Reduction in Livestock Program	PVC	Polyvinyl chloride	TM-LRR	Transmembrane leucine-rich repeat
MGEs	Mobile genetic elements	Q&A	Question & Answer	TN	Total nitrogen
MHRI	Manjimup Horticultural Research Institute	QLD	Queensland	ToBIMV	Tomato yellow blotch
MLA	Meat and Livestock Australia	qPCR	Quantitative polymerase chain reaction	TRVs	Traditional rice varieties
MLO	Mildew Locus O	QR	Quantitative resistance	TS	Traceability systems
MLR	Multivariate linear regression	QTL	Quantitative Trait Loci	TSP	Triple Superphosphate
Mn	Manganese	R&D	Research and Development	TT	Triazine-tolerant
MOOC	Massive Open Online Course	R,D&E	Research, Development, and Extension	UAN	Urea ammonium nitrate
MPS	Microplastics	RAB	Rwanda Agriculture and Animal Resources Development Board	UAV	Unmanned aerial vehicle
MRG	Microelectronics Research Group	RF	Random forest model	UK	United Kingdom
MRVs	Modern rice varieties	RGAs	Resistance gene analogs	UNE	University of New England
MS	Mass spectrometry	RLKs	Receptor-like kinases	USA	United States of America
MT	Melatonin	RLPs	Receptor-like proteins	USAID	United States Agency for International Development
N	Nitrogen	RMIT	Royal Melbourne Institute of Technology	USAID	United States Agency for International Development
NACRA	Northern Australia Crop Research Alliance	ROS	Reactive oxygen species	USQ	University of South Queensland
NaCRRRI	National Crops Resources Research Institute, Uganda	RP-HPLC	Reverse phase liquid chromatography	UWA	The University of Western Australia
NIL	Near-isogenic lines	RR	Roundup Ready®	WA	Western Australia
NLRs	Nucleotide-binding leucine-rich repeat	RTB	Roots, Tubers and Bananas	WAAA	Western Australian Agriculture Authority
NNSFC	National Natural Science Foundation of China	RTP	Research Training Program	WAARC	WA Agricultural Research Collaboration
NNTF	Number of nodes to flowering	RUSITEC	Rumen Simulation Technique	WAK	Wall-associated kinase
NPZ	Norddeutsche Pflanzenzucht	S	Sulfur	WAKL	Wall-associated kinase-like
NRMSE	Normalised root mean square error	SA	Salicylic acid	WALRC	Western Australian Livestock Research Council
NS	Non-stress	SaGE	UWA School of Agriculture and Environment	WH	Rainwater harvesting
NSMP	National Sheep Methane Program	SARDI	South Australian Research and Development Institute	WHI	Rainwater harvesting with irrigation
NSW	New South Wales	SAS	Shade Avoidance Syndrome	WHIOF	System integrating rainwater harvesting, irrigation, and organic fertilization
NSW-DPIRD	New South Wales Department of Primary Industries and Regional Development	SBR	Straw biochar	WUE	Water use efficiency
NUE	Nitrogen Use Efficiency	SCFAs	Short-chain fatty acids	WUEg	Grain water use efficiency
OF	Organic fertiliser	SLR	Systematic Literature Review	YCP	Yellow Cripps Pink
OR	Organic fertiliser	SNAGS	UWA's Students of Natural and Agricultural Sciences	ZNE	Zero Net Emissions
P	Phosphorus	SNP	Single nucleotide polymorphism		
PABRA	Pan Africa Bean Research Alliance	SNVs	Single nucleotide variation		
PBAF	Predictive Breeding for Agricultural Futures	SOC	Soil organic carbon		
PDA-TH NPs	Polydopamine-thymol nanoparticles	SOCs	Soil organic carbon sequestration		
P-EISS	Phosphorus-enriched industrial steel slag	SOM	Soil Organic Matter		
PHYB	Phytochrome B	SRNF	Slow-release nitrogen fertilisers		
PIP	Pilbara Innovation Partnership	SSA	Specific surface area		
PIRSA	Department of Primary Industries and Regions	SSWM	Site-specific weed management		
PIHtF	Plant height at flowering	ST	Tested straw		
PM	Plastic film mulching	STEM	Science, Technology, Engineering, and Mathematics		
PNUE	Photosynthetic N-use efficiency	STR	Struvite		
PPNIA	Peruvian Programa Nacional de Innovación Agraria	SVM	Support vector machines		
PPUE	Photosynthetic PUE	T	Temperature		
		TARI	Tanzanian Agricultural Research Institute		
		TGW	Thousand grain weight		

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