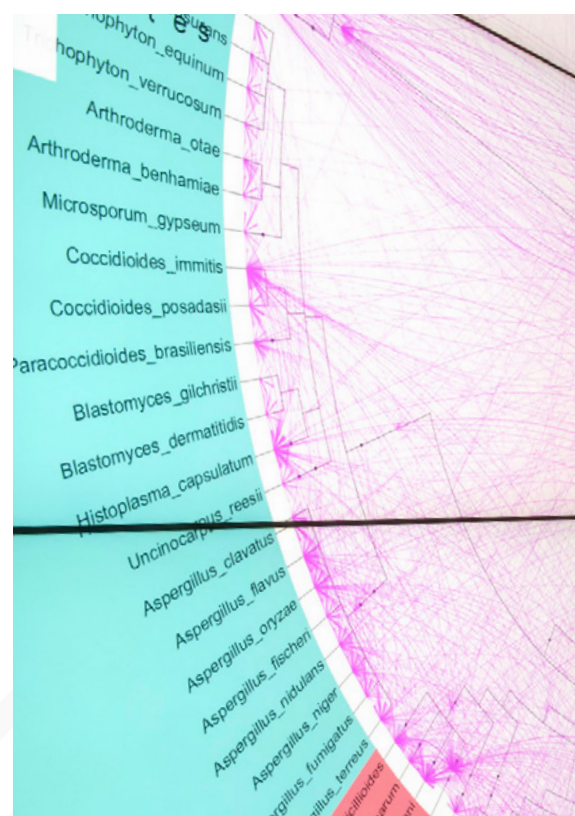
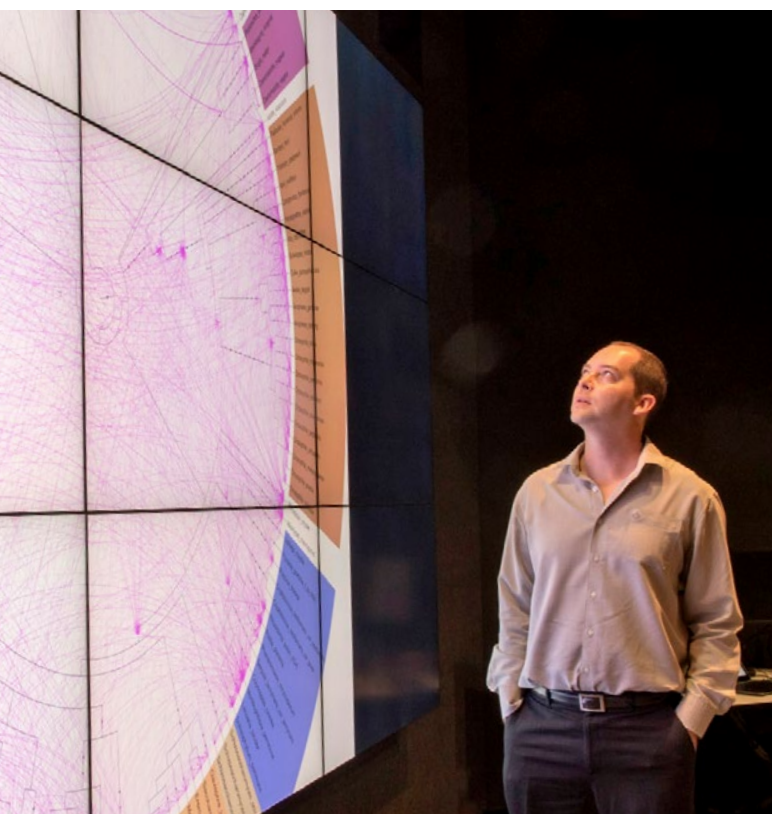


Centre for Crop and Disease Management

Centre Overview 2023





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Director's Report

Mark Gibberd
CCDM Director

Welcome to the 2023 centre overview for the Centre for Crop and Disease Management.

On reflection, 2023 has been a period of balanced growth with fantastic research outcomes continuing to be delivered by our more established programs. It has also been a year of professional development and capability building with a focus on our emerging leaders.

In 2023 we commenced the Analytics for the Australian Grains Industry (AAGI) project. This large project supersedes the highly successful previous investment in the Statistics for the Australian Grains Industry (SAGI). Importantly, AAGI builds on the statistics and biometry expertise developed in SAGI to provide national support for GRDC investments using all areas of data analytics. AAGI continues to provide foundation Biometry – the core of any experimentation – but now has access to a broader skill set spanning from bioinformatics through to advanced modelling, artificial intelligence and machine learning. CCDM is proud to partner with GRDC, the University of Adelaide and the University of Queensland as strategic partners in AAGI. From a Centre perspective Agricultural Data Analytics is a key area of

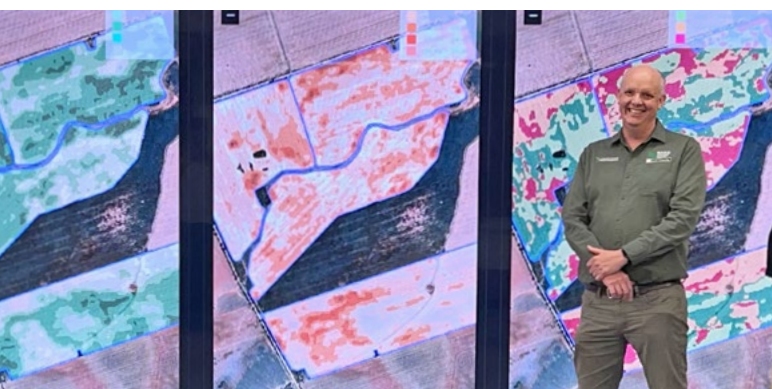
growth and strategic importance and the AAGI program both complements and adds depth to existing highly successful projects in our pathology program and our Curtin for Agribusiness Profitability group.

This report describes some remarkable achievements from within the CCDM. Of note are the fantastic outcomes in cereal pathology (Theme B) including the first Australian discovery of a critically important effector (Tox 8 – a protein formed by the pathogen that is responsible for cell death in the plant host) by Huyen Phan and significant progress towards delivery of new forms of resistance to net blotches in Barley through the work of Simon Ellwood.

Our canola and pulse pathology work (Theme C) continues to thrive under the leadership of Lars Kamphuis with a fantastic balance between applied outcomes (for delivery directly to plant breeders) and impactful publications based on new discoveries.

The battle against constant changes in the pathogen population continues to motivate all within the CCDM. Significant inroads have been achieved over the past 12 months in the detection, monitoring modelling and management of fungicide resistance (Theme A – Fran Lopez-Riuz) and in Themes B and C as we monitor and report on the genetic changes in the populations of key pathogens across time and space. This capability within CCDM is a key national strength and is supported by a team of dedicated molecular pathologist and bioinformatics experts. Their activities assist to identify and characterise changes in virulence or pathogen behaviour that may lead to failure of host resistance and to ensure that our research utilises the most appropriate array of pathogens when screening for new forms of resistance.

2023 has also been a high impact year for our Curtin for Agribusiness Profitability group. Led by Julia Easton this team is leading the charge for practice change based on





robust economic analysis of risk and return on investment at the sub-paddock scale and the development of tools and experimental processes enabling high utility on-farm trials. This research is characterised by a high level of engagement with growers, agronomists and farm business advisors and it is rewarding to see a steady uptake of on farm experimentation from many industry and research groups across the country.

The CCDM would not be able to function without its partnerships and we are extremely thankful for the support that we receive from our research partners, next- and end-users such as Australian breeding companies, global and local life science companies, industry representative groups, growers and allied industry members.

A key focus of CCDM is human development. In 2023, we have focussed on development of career opportunities for our next generation of leaders – our Early to Mid-Career Researchers (EMCR) – this has been an enjoyable and rewarding process and it is great to see five of our EMCR group achieve independent research income over the past 12 months.

On behalf of all CCDM staff and students I'd like to thank GRDC and Curtin for their continued commitment and support. Their support enables the CCDM to continue to deliver to Australian grain growers through our research outputs. It also ensures that we remain globally linked drawing new capabilities and research outputs into Australia from partners overseas.

CCDM Objectives

CCDM continues to be a leading Australian agricultural research centre with a focus on helping to reduce the economic impact of crop disease for the Australian grains industry. CCDM also works on other pathosystems outside of grains pathology and is increasing its capabilities in data analytics.

CCDM has three centre objectives:

1

Enduring profitability for industry

Creation of enduring profitability to the Australian Grains Industry by the delivery of adoptable innovative research outputs.

2

Improving capacity for industry

Deliver human capacity with relevant skills to meet the requirements of the partners.

3

Co-innovating with industry

Develop and support a co-innovation model with key industry participants and collaborators to build and sustain relevant research capability and deliver impact.

CCDM Structure

CUR00023 and allied projects

Fungicide Resistance

- Fungicide resistance characterisation and monitoring*
- Modelling fungicide resistance for decision support guidance*
- Early detection methods for fungicide resistance*
- Fungicide resistance Integrated Mapping Tool*
- Fungicide resistance in grapes (funded by Wine Australia)
- Australian Fungicide Resistance Extension Network (funded by GRDC)
- SAAFE CRC

Cereal Diseases

- Genetic resistance to fungal diseases affecting wheat*
- Genetic resistance to fungal diseases affecting barley*
- Pathogen dynamics and mechanisms of infection*

Canola and Pulse Diseases

- Sclerotinia stem rot of canola and pulses*
- Ascochyta blight of chickpea and lentil*
- Towards effective genetic and sustainable management of ascochyta blight of chickpea with ICARDA (funded by GRDC)
- Sclerotinia management for narrow leaf lupin crop in WA farming systems with DPIRD (funded by GRDC)
- Disease screening and diagnostics to identify fungal pathogens impacting safflower in WA (funded by GRDC)
- Investigating Bioclay™ for sclerotinia management in canola (funded by ARC)

Foundation Projects

- Advanced bioinformatic approaches*
- Plant physiological responses to fungal disease*
- Effector and co-infection biology*
- Fungicide dynamics*
- Impact, economics and engagement*
- Industry studentship (funded by Intergrain)
- Data Partnerships Initiative (funded by GRDC)
- Revitalising herbicides (funded by ARC)

* Projects funded by the GRDC project CUR00023

Curtin Biometry and Agricultural Data Analytics

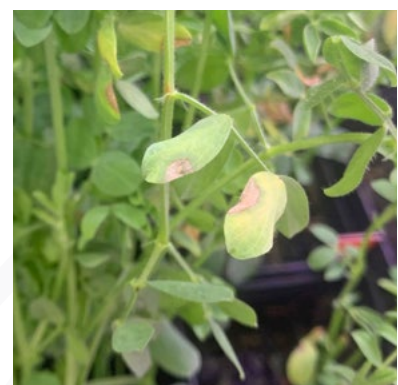
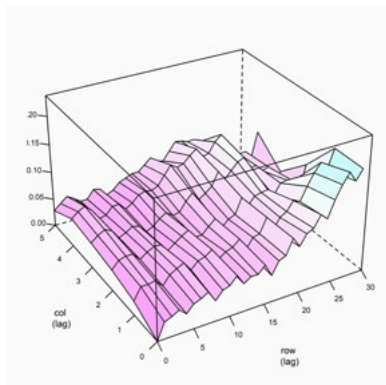
CBADA: Curtin Biometry and Agricultural Data Analytics

Analytics for the Australian Grains Industry (AAGI):

- CCDM is supporting more than 70 research projects with biometry, experimental design, bioinformatics, modelling and data analytics.

Curtin for Agribusiness Profitability (C4AP):

- On farm water demand in the South-West of WA (funded by Food Agility CRC)
- Digital Edge Program (funded by WA Government's Department of Jobs, Tourism, Innovation and Science)
- Digital Edge: next gen agribusiness analytics for the Eastern Wheatbelt (funded by Australian Government's Agricultural Innovation Hubs Program)
- Agri Analytics Hub (funded by Food Agility CRC)



CCDM Leadership Team



Mark Gibberd – CCDM Director

Mark has been involved in agricultural research for more than two decades and during that time has been a leader in ensuring the science CCDM conducts has real-world impact. His knowledge and expertise cuts across a range of industry sectors including horticulture, viticulture, water quality, crop disease management, agronomy, and agribusiness.



Jo Monaghan – Centre Business Manager

Jo has been with CCDM since 2016 and has seen the Centre grow from strength to strength over the years. She has been integral to developing the Centre's strategic and business plans, ensuring strong governance and supporting academic staff so that CCDM has impact in the industry. Jo has worked vertically across many aspects of agribusiness, including grain trading, manufacturing and logistics.



Fran Lopez-Ruiz – Theme Leader, Fungicide Resistance

Fran has been studying fungicide resistance since 2002 and completed his PhD at University of Malaga (Spain) and the John Innes Centre (UK) in 2010. Since joining Curtin University in 2011, Fran has led the Fungicide Resistance Group, which aims to understand how fungicide resistance develops and how to improve the management of fungicides to reduce the impact of diseases in the field.



Simon Ellwood – Theme Leader, Cereal Diseases

Simon has pioneered fundamental research into resistance to plant fungal diseases and in both plant and fungal genomics. He has published widely in some 31 journals and collaborates with researchers in each continent. At the CCDM, he leads the Cereal Diseases Theme, investigating five important diseases of wheat and barley.



Lars Kamphuis – Theme Leader, Canola and Pulse Diseases

For the past two decades, Lars' research interests have centred on investigating the mechanisms of plant resistance to biotic stresses from diseases and pests and legume genomics. In addition to his role as Theme Leader for Canola and Pulse Diseases, Lars is one of the partners in the ARC Hub for Sustainable Crop Protection.



Adam Sparks – AAGI Technical Lead

With over twenty years' experience, Adam has been part of different organisations in agricultural research in academia, an international NGO and state government. His interests and expertise include modelling, plant pathology, epidemiology, agronomy, crop disease management, biometry and programming with a strong ethos of open science and reproducible research.



Julia Easton – C4AP Group Leader

Julia has an extensive background in research management, and since joining CCDM in 2019 has helped create enduring partnerships and co-investment opportunities with the agriculture industry. Julia leads the the Curtin for Agribusiness Profitability (C4AP) Initiative, aiming to deliver next generation agribusiness research to underpin future farm profitability and sustainability.



Theme A: Fungicide Resistance

Fran Lopez-Ruiz

Theme Leader

Associate Professor

Email: fran.lopezruiz@curtin.edu.au

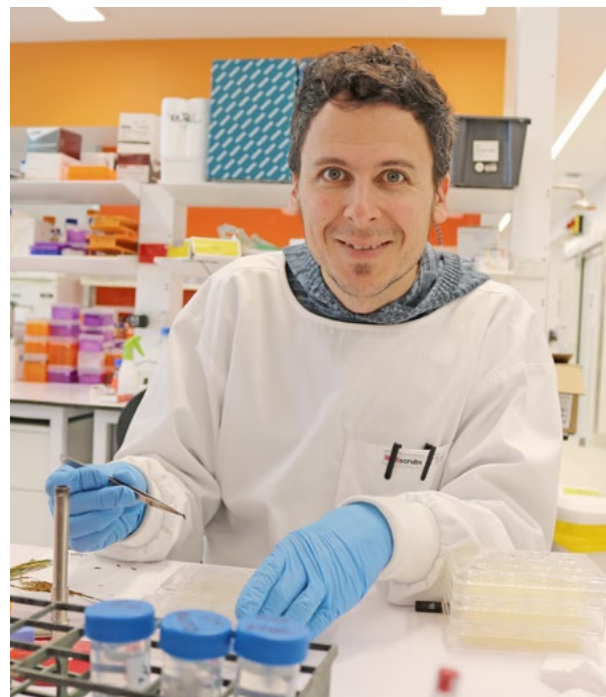
Since the first Australian discovery of fungicide resistance in 2010, this Theme has continuously focused on finding solutions for growers faced with fungicide resistance on their properties. Today, industry is much better equipped with knowledge on how resistance develops, and how to reduce the risk of it developing further.

The Fungicide Resistance Theme has contributed to some of the most outstanding scientific developments in fungicide resistance research world-wide, and continues to do so by following a high-impact research model focused at providing practical solutions to fungicide resistant disease.

The combination of new knowledge and capabilities developed by this theme has allowed the Australian grains industry to be at the forefront of fungicide resistance awareness and management.

The aim of this theme is to develop and demonstrate management packages for industry designed to combat pathogens under conditions of fungicide resistance.

Furthermore, the theme will seek to demonstrate the capacity to avoid or delay the onset of fungicide resistance through early detection and informed fungicide management practices.



CCDM researcher and Theme A leader Fran Lopez-Ruiz

Theme A Projects	Funding body
Fungicide resistance characterisation and monitoring	GRDC (CUR00023)
Modelling fungicide resistance for decision support guidance	GRDC (CUR00023)
Early detection methods for fungicide resistance	GRDC (CUR00023)
Fungicide Resistance Integrated Mapping Tool	GRDC (CUR00023)
Australian Fungicide Resistance Extension Network (AFREN)	GRDC (CUR2302-002RTX)
Fungicide resistance in grapes	Wine Australia

Fungicide resistance characterisation and monitoring – keeping tabs on the situation across Australia

CCDM project team: Fran Lopez-Ruiz (Project Leader), Kejal Dodhia, Wesley Mair, Steven Chang, Katherine Zulak, Liz Czislawski and Chala Turo.

Key points

- By using high-throughput technologies to rapidly confirm the extent of fungicide resistance in wheat powdery mildew across Australia, CCDM was able to support the issue of an emergency permit for other fungicides to be used to manage the epidemic.
- Monitoring, efficacy studies and resistance characterisation have seen CCDM become the biggest source of fungicide resistance research outputs in the country.
- This research has led to significant practice change among Australian growers on the best way to manage disease with fungicide resistance through their contributions to the AFREN fungicide resistance extension investment.

In Australia, a number of grain diseases have recently developed resistance to some fungicide actives sparking concerns within the industry (Figure 1). The limited availability of cheap and effective chemistry, together with the use of tight crop rotations in many cases, have contributed to the fast onset of resistance.

This project has a strong history of delivering management alternatives to fight fungicide resistance. The research team have continued to provide seasonal monitoring of fungicide resistance in grains diseases paying particular attention to diseases of high concern to the industry. Although disease pressure across all growing regions has been generally low due to less conducive weather conditions during 2023, high prevalence of DMI and QoI resistance has continued to impact disease control in regions traditionally affected by these diseases.

Recently, fungicide performance under controlled conditions was characterised for fungicide resistant pathogens causing wheat powdery mildew and barley net blotches. The analysis of DMIs commonly used for the control of wheat powdery mildew has revealed that the disease is not fully controlled at the highest registered rates for any of the fungicides tested. Similarly, common DMI and SDHI fungicides used for the management of barley net- and spot-form net blotch were not able to control resistant strains of the pathogens under controlled conditions. The results suggest that the main actives used for the management of these pathogens are no longer effective in the presence of resistant populations when disease conditions are conducive and risky agronomic practices are followed.

The major impact of this project can be seen across the entire Australian grains industry, where significant practice change has been observed following the extension of tangible outcomes from the monitoring,



CCDM researchers Fran Lopez-Ruiz, Kejal Dodhia and Wesley Mair in a WA barley field.

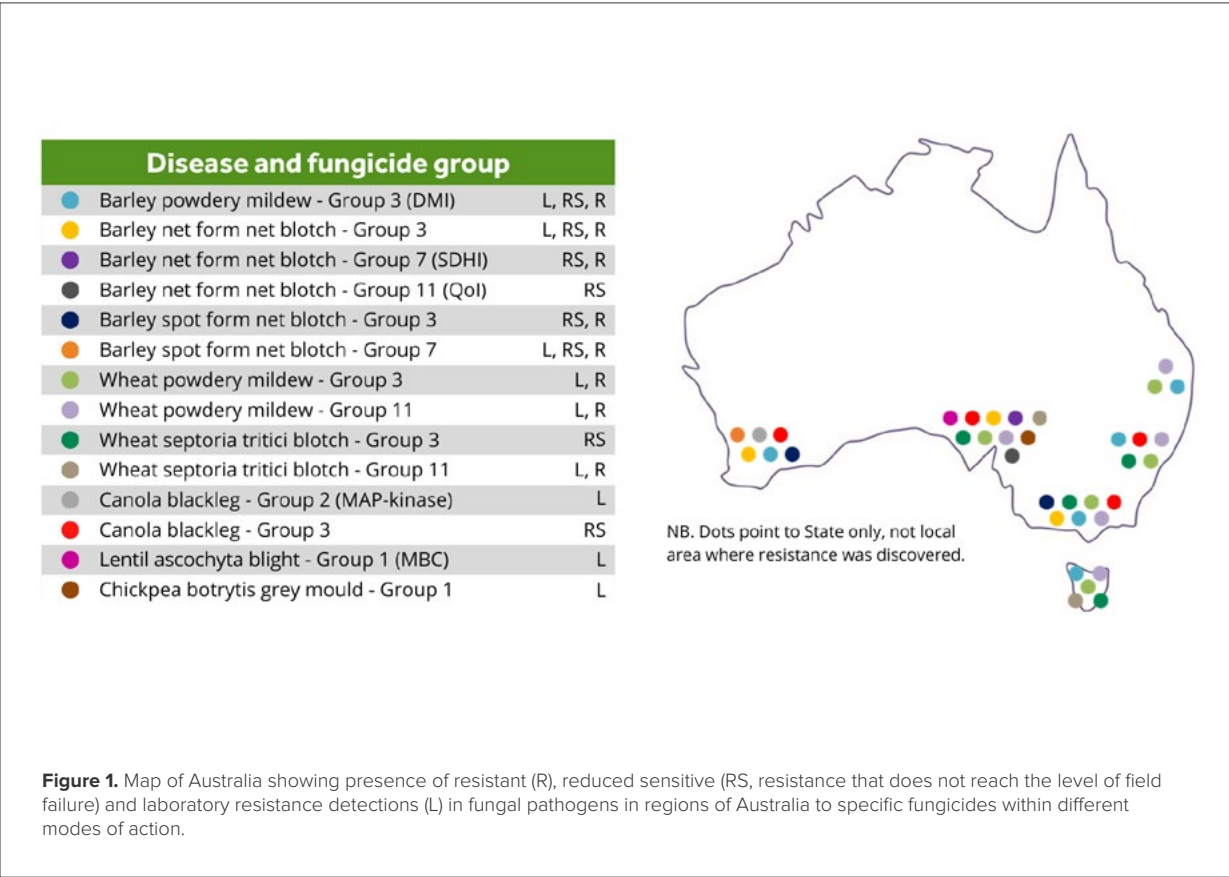


CCDM's fungicide resistance outputs have led to significant practice change among Australian growers

efficacy studies and resistance characterisation conducted by the research team. For example, when many growers experienced major fungicide resistance issues when trying to control wheat powdery mildew, the research team were able to contribute work and information that led to the issue of an emergency permit for the products quinoxifen and proquinazid (Group 13) and metrafenone (Group 50). Having access to two additional modes of action to control wheat powdery mildew means that industry will have a higher diversity

of modes of action to control the disease going forward. Sharing extension messages through the Australian Fungicide Resistance Extension Network (AFREN), this project has been essential for all Australian grain growers, ensuring solutions are there to help control the build-up of fungicide resistant populations in the paddock.

This project is funded by the Grains Research and Development Corporation.



CCDM researchers Kat Zulak, Chala Turo and Liz Czulowski work on fungicide resistance in the lab



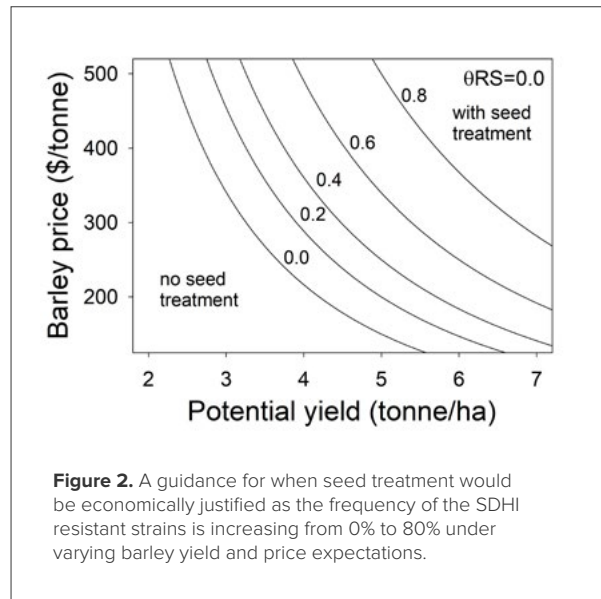
Powdery mildew on wheat stubble

Modelling resistance: A framework for when to apply SDHI fungicide seed dressing to barley when battling with SDHI resistance

CCDM project team: Ayalsew Zerihun (Project Leader), Frank van den Bosch and Kul Chandra Adhikari.

Key points

- CCDM has successfully developed a data-model-informed practical guide for when to adjust fungicide treatments when dealing with fungicide resistance.
- The provision of such guidance is expected to inform barley growers to make economical fungicide treatment decisions, even when resistance is increasing.
- By integrating experimental data with epidemiological modelling, CCDM has delivered an unparalleled opportunity to provide barley growers with actionable resistance management tactics.



Detections of resistance to DMI and SDHI fungicides in both net-form and spot-forms of net blotch have increased in recent years, and rigorous guidance on how to manage resistance is in high demand across Australian barley growing regions.

This CCDM project has been able to address these challenges head-on by successfully developing a data-model-informed practical guidance for when it would be economically beneficial to adjust fungicide treatment programme when SDHI resistance is increasing in the pathogen that causes spot-form net blotch of barley.

By using a model that was previously developed by this research team for DMI resistance in spot-form net blotch, the team were able to parametrise this model for SDHI resistance in the same pathogen, using fluxapyroxad dose response data. The research team once again used a hybrid approach of combining field experimentation and modelling to deliver the guidance, where the data from the field experiment underpins the modelling component of the project.



Spraying to control net-form and spot-form net blotch



Spot-form net blotch of barley

The research team were able to show that the optimal treatment program is strongly dependent on both the potential yield of the paddock under consideration and the barley market price. Furthermore, when SDHI resistance increases in the spot-form net-blotch population, the combinations of potential yield and barley market price where the use of the SDHI seed treatment is economically justified, change (Figure 2). The team were able to show there is no benefit to using SDHI seed dressing to control net blotches when the pathogen populations are dominated by reduced sensitive and/or resistant types.

The provision of such guidance is expected to inform barley growers to make profitable fungicide treatment decisions, even when resistance is increasing. By integrating experimental data with epidemiological modelling, CCDM has delivered an unparalleled opportunity to provide the Australian barley growers with actionable resistance management tactics.

This project is funded by the Grains Research and Development Corporation.



CCDM researcher Ayalsew Zerihun



CCDM researcher Kul Chandra Adhikari at a Muresk field trial in WA

Early detection methods: Using nanopore sequencing technology to improve fungicide resistance detection

CCDM project team: Katherine Zulak (Project Leader) and Lina Farfan-Caceres.

Key points

- The MinION sequencing device has improved the ability to monitor fungicide resistance mutations in spot-form and net-form net blotch - diseases that both have multiple forms of resistance arising from a complex array of potential mutations.
- CCDM can now capture both known and novel mutations with one assay.
- The ability to screen large numbers of samples has significantly improved, which will help growers make relevant management decisions.

As mutations rapidly evolve with increasing selective pressure, an on-demand detection technology that captures this complex set of evolving mutations is critical. However, amplification-based technologies such as LAMP, qPCR and digital PCR have become complicated and time consuming, especially in a rapidly evolving resistance landscape.

This CCDM research team have found a solution to quickly detect fungicide resistance from barley samples direct from the field, using the small portable DNA sequencer from Oxford Nanopore Technologies. The MinION device has reduced the need for multiple lab tests for the same outcome and have overall improved screening pipelines for detecting fungicide resistance.

Focusing on both spot-form and net-form net blotch of barley due to the major fungicide resistance issues caused by the diseases, the team developed a long-read sequencing assay for the azole target gene *Cyp51*. This particular target gene can have different mutations that occur in two different regions, complicating resistance detection.

Their new method has been able to capture all known mutations in both spot-form and net-form net blotch, as well as their hybrids, with a single assay while simultaneously distinguishing between forms, combining species identification with fungicide resistance status. Importantly, since the assay does not depend on prior knowledge, it can also simultaneously characterize new mutations as they arise.

The newly developed pipeline using the MinION device is currently being used as an initial screen to quickly determine the resistance profile of paddock samples and flag any new mutations. This new capability will help to speed up fungicide resistance testing, and together with extension support through the Australian Fungicide



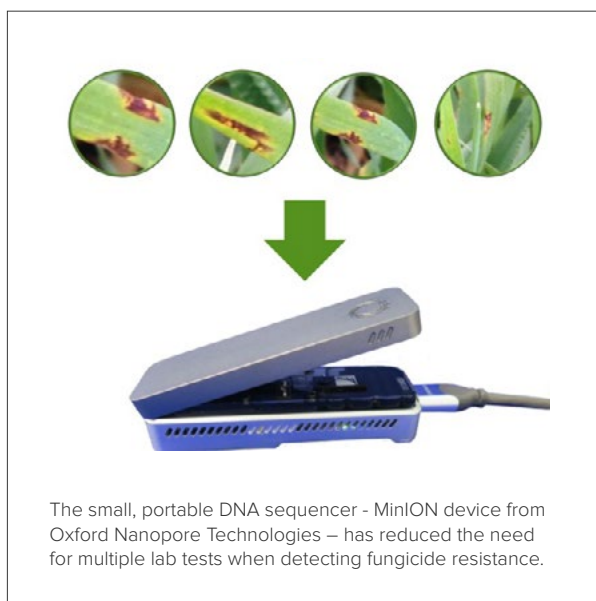
Net-form net blotch of barley



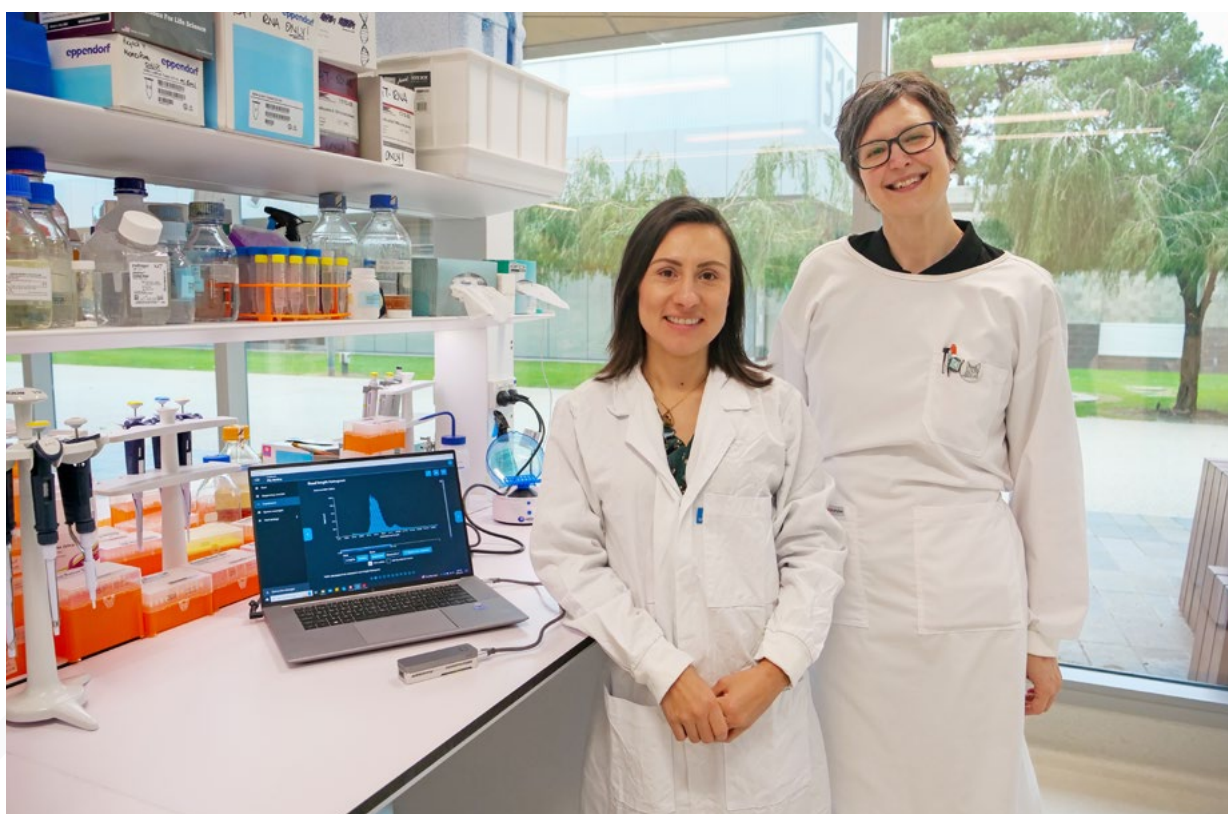
CCDM researchers Katherine Zulak and Lina Farfan-Caceres examining field samples in the laboratory

Resistance Extension Network (AFREN), has helped ensure resistant pathogens have not reached epidemic heights.

This project is funded by the Grains Research and Development Corporation.



CCDM researcher Lina Farfan-Caceres loading up the MinION device with DNA samples



CCDM researchers Lina Farfan-Caceres and Katherine Zulak work together on fungicide resistance research using the MinION device

New mapping tool for data-driven fungicide resistance decisions

CCDM project team: Fran Lopez-Ruiz (Project Leader), Leon Hodgson and Lina Farfan-Caceres.

Key points

- A new data visualisation tool can show the nation-wide severity of fungicide resistance across several key pathosystems, and estimate the risk of fungicide resistance developing.
- This tool is the first of its kind in helping growers make data-driven decisions best suited to their region, drawing on an enormous database of fungicide resistance testing results.
- As more sample data is fed into the tool, the more accurate the fungicide resistance status becomes, removing the guesswork from disease management, and improving profitability.

While fungicide resistance is now a concept reasonably well understood by the grains industry, the adoption of the improved control strategies required to manage this problem are not occurring at the desired rate. One of the reasons why this is not happening fast enough is the sheer size of the land cropped to grains in Australia

and the relatively low fungicide resistance data density generated relative to that size.

To solve this problem, this project has partnered with the Analytics for the Australian Grains Industry (AAGI) program and the geospatial technology company NGIS, producing a visualisation tool that can provide landscape scale analytical and data visualisation capabilities to benchmark fungicide resistance levels across several key pathosystems. To build this tool, major datasets were compiled using historic sample information on genetic mutations and associated GPS data to build a map that displayed fungicide resistance distribution (Figure 3).

The tool allows the user to choose between different crops, diseases, fungicide treatments and grid size. It also has a fungicide resistance risk calculator that allows the user to estimate the value of the resistance risk by selecting the crop rotation strategy, variety disease rating and fungicide program. The tool will then calculate the resistance risk taking into account these factors and the particular dispersion strategy of the pathogen (i.e. airborne vs stubble borne).

The final version of the visualisation tool will be available to all industry members in 2024. This version will include four pathosystems for which fungicide resistance has acquired important levels of concern within the industry in recent years, including wheat powdery mildew, barley net form and spot form net blotch, and wheat septoria tritici blotch.



CCDM researchers Kejal Dodhia and Fran Lopez-Ruiz sampling for fungicide resistance in the wheatbelt



Powdery mildew on wheat

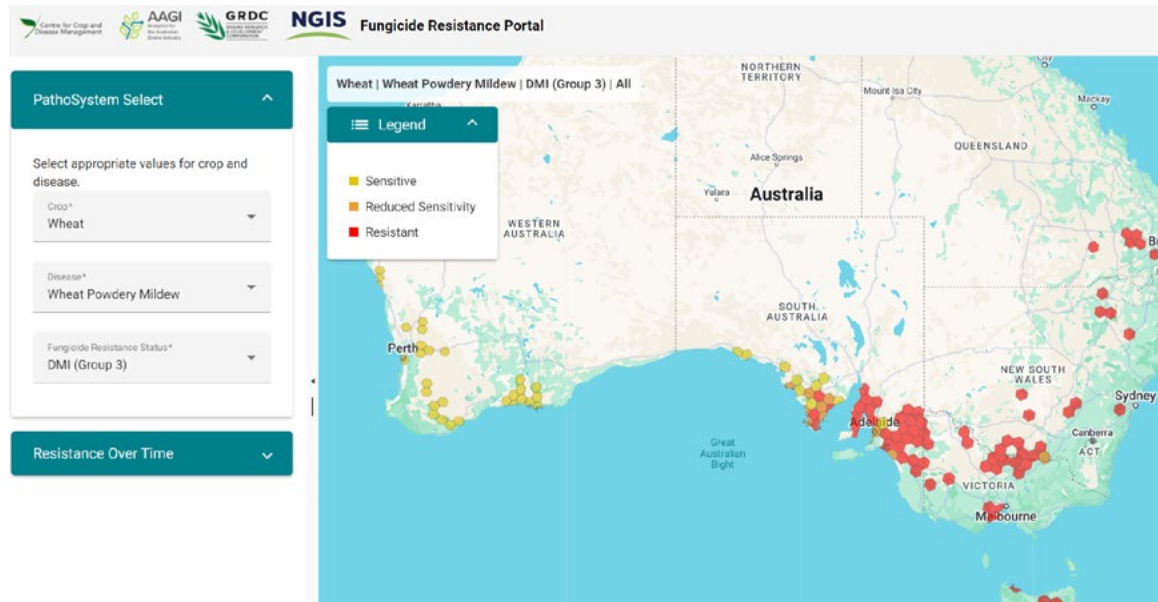


Figure 3. The new data visualisation tool generated in collaboration with Analytics for the Australian Grains Industry (AGI) showing where DMI (Group 3) fungicide resistance has been found in wheat powdery mildew.

The impact of this relevant resource is not only in the mapping of fungicide resistance but also in the estimation of its risks so that growers can make the right decision for their property. Furthermore, as more data is fed into the tool, and in parallel with extension packages from the Australian Fungicide Resistance Extension Network (AFREN), decisions around crop and chemical use have become data-driven, ensuring the best possible decisions are made for improving the management of fungicide resistance across the entire grain growing region.

This project is funded by the Grains Research and Development Corporation.



The new tool can help growers better understand the risk of fungicide resistance developing in their paddocks



CCDM researcher Leon Hodgson helped create the new data visualisation tool

AFREN: Spreading the messages the messages on fungicide resistance across Australia

CCDM project team: Fran Lopez-Ruiz (Project Leader) and Anna-Sheree Krige (Project Coordinator).

Collaborators: Ag Communicators, ICAN, Agriculture Victoria, SARDI, DPIRD, FAR Australia, Marcroft Grains Pathology, NSW DPI, Queensland Government, University of Southern Queensland, University of Sydney, University of Melbourne.

Key points

- AFREN's interactive regional workshops, field days and communication initiatives have empowered growers and agronomists to make informed decisions about fungicide use.
- In 2023, three two-day regional workshops were delivered in Perth, Narrogin and Adelaide, engaging 72 attendees in total, and rating 4.7 out of 5 for value.
- Significant practice change amongst Australian growers has been observed following the extension of research outputs by AFREN's experts.

The development of fungicide resistance and the limitation of available fungicide Mode of Actions (MoAs) is an ongoing issue for grain growers. In response to this continuing concern, the CCDM-led Australian Fungicide Resistance Extension Network (AFREN) has been successful in delivering tailored

training workshops and a suite of digital resources in accordance with the most up-to-date research, addressing management strategies which are crop, disease and region specific. The high-impact activities in 2023 included the interactive regional two-day workshops, immersive field days and communication initiatives.

Two-day regional workshops

AFREN conducts workshops and training sessions across the country, empowering growers and agronomists with knowledge and resources on hand, to make informed decisions about fungicide use. In 2023, three two-day regional workshops were delivered in Perth, Narrogin and Adelaide, focusing on foliar diseases and fungicide resistance management strategies.

Feedback from these regional workshops highlighted a positive response, with growers and agronomists reporting increased understanding of the issue and a greater willingness to adopt integrated disease management strategies. In terms of value, the workshops rated exceptionally high, with the average rating being 4.7 out of a possible 5. A total of 72 attendees participated at the workshops (excluding speakers), with both Perth and Adelaide workshops reaching maximum capacity.

Half day field day at Muresk

AFREN will often incorporate presentations and information into industry field days and workshops where messaging around fungicide resistance is needed. In collaboration with CCDM, AFREN hosted a field day and workshop at the Muresk field trial area in August 2023. This workshop presented the latest research in evaluating field efficacy of DMI and SDHI fungicides against barley net blotches, a topic of high concern in the region. An overview of how spatial modelling can help predict efficacy of DMI fungicides was covered, followed by a discussion concerned with optimising the guidance on treatment programmes under high disease pressure conditions (i.e. increasing resistance). Field trial observations were included with further discussions surrounding the latest guidance for fungicide resistance management.

Fungicide resistance testing at the FAR field day

In collaboration with researchers from CCDM and experts from FAR Australia, AFREN provided growers and agronomists the opportunity to test their crops



CCDM researchers and agronomists at the AFREN half day field day at Muresk

for fungicide resistance at the October 2023 'Hyper-Yielding Crops and Pulse Agronomy Annual Field Day' held in Victoria. Attendees had access to resources on best management strategies, including copies of the *Fungicide Resistance Management in Australian Grain Crops* guide. For those who submitted samples for screening, testing results were available post-event.

AFREN information dissemination on fungicide resistance management

The AFREN network, comprising plant pathologists and communication experts, has been successful in disseminating information through its regularly updated website afren.com.au. The site has continued to feature news updates and a wealth of online resources, including webinars, videos, podcasts, factsheets, case studies and a digital copy of The Fungicide Resistance Management in Australian Grain Crops guide, ensuring the latest knowledge on fungicide resistance is always accessible.

Given the challenges of attending in-person workshops, AFREN has ensured industry access to a suite of digital tools that include podcasts, webinars and videos, all of which have received high engagement rates. These online resources featured updates from expert interviews, fostering a sense of connection within the agricultural community, and keeping industry members updated on evolving trends, new research and best management practices for their crops.

The distribution of a Groundcover Supplement on Fungicide Resistance to the national grains industry has significantly raised awareness and promoted informed decision-making regarding best management practices. This supplement showcased AFREN messaging and the latest CCDM research, along with contributions from partner research institutions focused on fungicide resistance in Australian grain crops.

In summary, AFREN has been successful in promoting resource development, maintenance, and dissemination while fostering a strong network of experts to benefit the grain industry in the fight against fungicide resistance. The CCDM-led project will continue to grow, collaborate, and share knowledge, showcasing a wide-reaching and impactful engagement with the agricultural community.

This project is funded by the Grains Research and Development Corporation.



Inspecting crops and talking about fungicide resistance at an AFREN field day



CCDM researchers Lincoln Harper, Anna-Sheree Krige and Fran Lopez-Ruiz carrying out fungicide resistance testing



Fungicide resistance discussions by AFREN at a recent field day

Fungicide resistance solutions for grape producers

CCDM project team: Fran Lopez-Ruiz and Lincoln Harper.

Collaborators: South Australian Research and Development Institute (SARDI).

Key points

- Fungicide resistance testing has advanced significantly in the wine and grape industry, allowing a clearer picture of the issue.
- This research team have delivered protocols for high throughput laboratory and in-field genotypic testing of fungicide resistance for three major diseases affecting grapevines.
- Rapid and accurate diagnosis of fungicide resistance will enable producers to put in place the relevant management strategies to reduce the likelihood of resistance development and/or progression.

The grapevine diseases powdery mildew (*Erysiphe necator*), botrytis bunch rot (*Botrytis cinerea*) and downy mildew (*Plasmopara viticola*) are the most significant diseases in grapevine. Botrytis bunch rot alone is estimated to cost the Australian wine and grape industry on average \$50 million per year. With a limited number of fungicides available in wine grapes, fungicide resistance is a major concern amongst wine producers.

This project has been successful in establishing fungicide baselines for the major fungicides used by the industry, and developing and optimising both in-field and high-throughput laboratory genotypic testing, for improved monitoring of fungicide resistance. Together with conventional phenotypic and molecular sequencing techniques, this research has been able to support grape and wine producers to make informed decisions about spray programs and resistance management.

During the 2023 season, high throughput laboratory and in-field genotypic testing were evaluated for their capability to identify two common fungicide resistant mutants, known as G143A (Group 11) and L412F (Group 9) in *E. necator* and *B. cinerea*. Using the relevant

molecular markers, all testing methods were successful in identifying both mutants.

Because of this research, genotypic testing through high-throughput laboratory and in-field methods can now be used alongside phenotypic testing to detect fungicide resistance in the wine grape industry. With advanced diagnostic techniques, simple and rapid fungicide resistance results can be communicated to producers, so they can put in place the relevant management strategies to reduce the likelihood of resistance development and/or progression.

This project is funded by Wine Australia.



CCDM researcher Lincoln Harper working on grapevine diseases



Botrytis bunch rot sporulating in grapes



Theme B: Cereal Diseases

Simon Ellwood

Theme Leader

Associate Professor

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The yield and profitability of barley and wheat are significantly impacted by fungal diseases which result in multimillion dollar losses and control costs annually. The Cereal Diseases Theme works to reduce the impact of four major cereal diseases by working with breeding companies to improve disease resistance in wheat and barley.

While fungicides are widely used for disease control and can offer short-term solutions to disease pressure, crop genetics offers the best long-term advantage by improving varietal disease resistance which not only limits disease losses, but also prolongs the useful life of fungicide chemistries and other control measures.

With a solid foundation and knowledge base in pathogen biology, this Theme has developed a suite of core capabilities and key resources including world-first pathogen genetic manipulation techniques, extensive national isolate collections, pathogen reference genomes, genetic mapping resources and the discovery of new sources of disease resistance.

Going forward the Cereal Diseases Theme will prioritise identifying and characterising genetic resistance. For wheat, yellow spot and septoria nodorum blotch remain as priority breeding targets, both of which exert high impacts on wheat production, particularly in WA.

For barley, both net and spot forms of net blotch continue to be breeding targets of high priority, with significant impacts on national production.



CCDM researcher and Theme B leader Simon Ellwood

Theme B Projects	Funding body
Genetic resistance to fungal diseases affecting wheat	GRDC (CUR00023)
Genetic resistance to fungal diseases affecting barley	GRDC (CUR00023)
Pathogen dynamics and mechanisms of infection	GRDC (CUR00023)

Wheat genetics: New effector-receptor interactions greatly improve cereal breeding

CCDM project team: Huyen Phan (Project Leader), Eiko Furuki and Fiona Kamphuis.

Key points

- CCDM is a leading lab in the world with two new necrotrophic effector-receptor gene interactions between wheat and the pathogens causing yellow spot and septoria nodorum blotch discovered and characterised.
- Disease susceptibility and resistance mechanisms identified by this team has explained the complexity and qualitative natures of both yellow spot and septoria nodorum blotch diseases.
- This research has enabled a future where crop disease can be managed by genetics – the most economical and sustainable way to manage disease.

Yellow spot (YS) and septoria nodorum blotch (SNB) are two major fungal diseases that use necrotrophic effectors to cause necrosis on wheat varieties that have matching susceptibility genes. CCDM has a long history for discovering effectors in pathogens and the receptor genes in wheat, with nine major necrotrophic effector-receptor gene interactions defined within these two pathogens to date. Such discoveries lead to perfect to near-perfect markers, allowing wheat breeders to remove susceptible loci and increase SNB and YS resistance, reducing the economic impact of disease for Australian growers.

The most recent interaction discovery is SnTox8 in the SNB pathogen and ToxF in the YS pathogen and their interaction with 2AL QTL in wheat. The research team have now progressed to find the location of the Snn8 sensitive receptor gene in 2AL QTL. To obtain a list of gene candidates, a RNAseq experiment was set up with wheat varieties Mace and Lancer, and markers for a few candidate genes were developed for 2AL QTL region. Testing these markers on a Mace x Lancer double haploid population and 94 wheat commercial lines show significant correlation between the presence of the marker and Tox8 sensitivity trait.

Along with other receptor genes discovered thus far, the identification of Snn8 accounts for almost all disease susceptibility in this region, ensuring breeders have additional tools they need to improve disease resistance in wheat.

This team have also taken effector discovery a step further with the identification of another novel effector in the SNB pathogen in 2023, naming it SnTox9, with the novel interaction with wheat gene Snn9 yet to be characterised in 2024.

While discovering effector-receptor gene interactions is the majority of this project, the research team have also



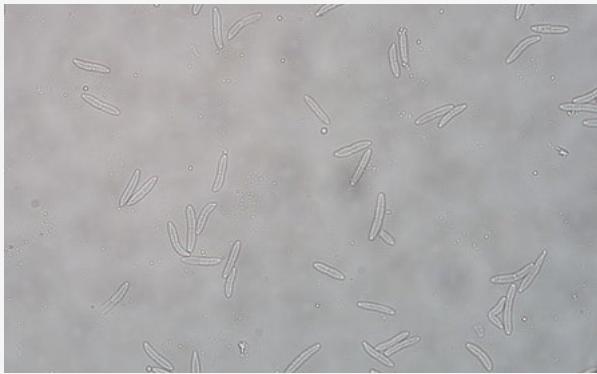
Yellow spot of wheat



CCDM researcher Eiko Furuki in the CCDM laboratory

established the breadth of diversity of the SNB pathogen, with genetic diversity analysis indicating three new pathotype groups further to the five formally detected. Two of these new groups were revealed to be more pathogenic than the other groups. Information such as this, as well as genetic tools that are proven to improve resistance in wheat, are enabling a future where crop disease is managed by genetics – the most economical and sustainable way to manage disease.

This project is funded by the Grains Research and Development Corporation.



A microscopic view of spores from the pathogen causing septoria nodorum blotch



A CCDM effector infiltration experiment



CCDM researcher Huyen Phan examining a wheat experiment in the glasshouse



CCDM researchers Asiri Anushka Padukka Vidanalage, Huyen Phan and Fiona Kamphuis in CCDM's Field Trial Area

Barley genetics: Breeding barley with resistance against net blotches

CCDM project team: Simon Ellwood (Project Leader), Hoan Dinh, Nola D'Souza and Julie Lawrence.

Key points

- This project has been successful in discovering new barley genes from diverse landraces, with much stronger levels of resistance than current Australian varieties.
- For the first time, the barley team has developed a mutagenised barley population to remove net blotch susceptibility loci in an elite cultivar background and to discover new resistance genes. The population has multiple applications for other diseases and agronomic traits.
- With leading-edge methodologies and extensive collaborations, this research team are providing barley breeders with germplasm, tools and knowledge to combat net blotch diseases.

The barley diseases spot and net forms of net blotch are regarded with high concern by breeders, with effective sources of resistance limited in Australia. Because of this concern, the CCDM barley team provides grower-targeted solutions for improving resistance levels, by building on existing resources and expertise that include disease phenotyping, host segregating populations, pathogen genomics and population structures and extensive isolate collections. Recently, the team initiated a mutagenised barley program to remove net blotch susceptibility loci in an elite cultivar background and to discover genes that may not be available in existing germplasm resources.

For the past two years, this project has been successful in discovering new barley genes from diverse landraces from other countries. These have much stronger levels of resistance than current Australian varieties and this knowledge is being passed onto breeders.

For spot-form net blotch (SFNB) resistance, the project team also discovered a major susceptibility gene to SFNB that masks a minor seedling resistance gene. According to the researchers, partial or minor resistance genes are regarded as potentially durable but appear more likely to break down if single genes are involved, as is the case in several current varieties that carry such minor seedling resistance. For improved net-form net blotch (NFNB)



CCDM researchers Nola D'Souza and Julie Lawrence preparing a barley disease experiment

resistance, the team have discovered a subset of NFNB resistance genes effective against a panel of current Australian pathotypes.

By using the most up to date methodologies and collaborating with a wide range of researchers, this team is providing barley breeders with germplasm, tools and knowledge to combat both net blotch diseases. Improving disease resistance will be enhanced by integrating research outputs within the context of genomic selection and traditional breeding methods, as well as enabling multigenic gene stacking options.

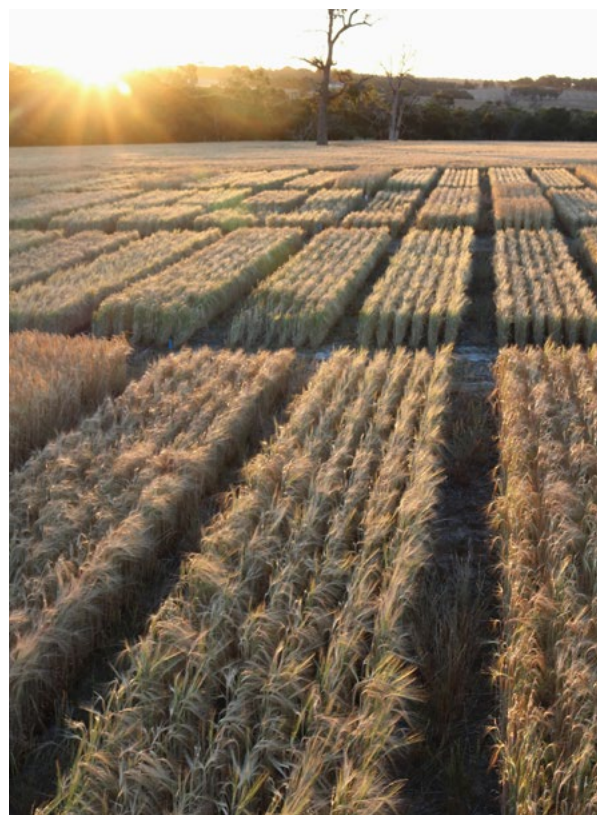
This project is funded by the Grains Research and Development Corporation.



Net-form net blotch screening in barley



CCDM researchers Julie Lawrence, Sundara Link and Hoan Dinh in the CCDM laboratory



Barley National Variety Trial in the wheatbelt



CCDM researcher Simon Ellwood works on both spot-form and net-form net blotch

Pathogen dynamics: Monitoring for changes in virulence in common cereal pathogens

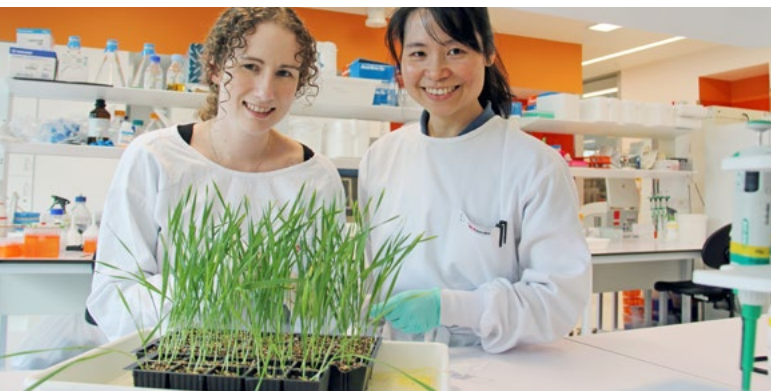
CCDM project team: Pao Theen See (Project Leader), Elyce Iagallo, Kalai Marathamuthu and Catherine Cupitt.

Key points

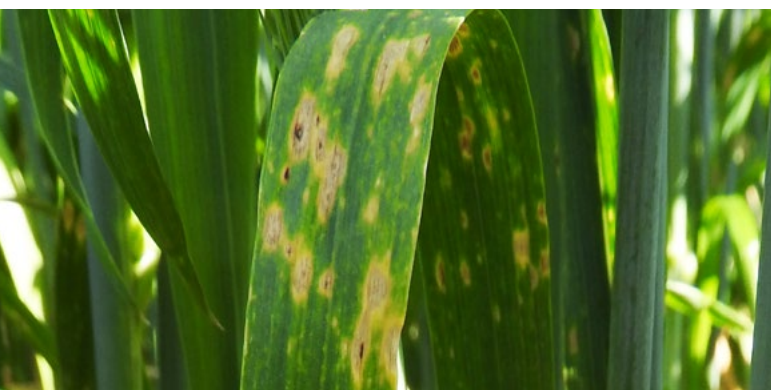
- An online resource of fungal isolates has ensured breeders and researchers have the most current Australian yellow spot and septoria nodorum blotch pathotypes at hand.
- Availability of virulence factor kits to breeders and researchers enabled rapid screening for wheat susceptibility to yellow spot and septoria nodorum blotch in a cost-effective way.
- The completion of yellow spot pathogen *Pyrenophora tritici-repentis* pathotyping and virulence profiling has highlighted the importance of developing wheat varieties without the receptor gene *Tsn1*.

Pathotype surveillance of the wheat diseases yellow spot and septoria nodorum blotch is essential to understand the dynamics and ever-changing pathogen populations across Australian grain growing regions. This CCDM project delivers up to date pathogen status information to breeders and researchers to ensure new varieties are resistant to the current most dominant pathotypes in Australian fields.

Recently this research team made significant progress in yellow spot research with the completion of yellow spot pathogen *Pyrenophora tritici-repentis* pathotyping and virulence profiling. Results have shown that despite the broad distribution of yellow spot in Australia, the isolates selected from across the different cropping regions have relatively low variability or complexity in virulence and pathotypes. The Australian yellow spot population mainly consists of a predominant pathotype (race 1) that produces the virulence factors ToxA and ToxC. While a mutation on the major virulence gene ToxA has been reported in overseas YS isolates, CCDM's surveillance in Australian YS isolates has found no ToxA mutation. This finding highlights the importance for breeders to continue to develop wheat varieties that are without the corresponding wheat receptor gene *Tsn1* in Australia.



CCDM researchers Elyce Iagallo and Pao Theen See



Yellow spot on wheat

Utilising the molecular tools developed over the past few years, CCDM continues to provide information on wheat sensitivity to virulence factors in yellow spot and septoria nodorum blotch. Working closely with breeders to select disease resistant wheat lines, the project has also established an online resource of fungal isolates and virulence factor kits. By making available the most current Australian yellow spot and septoria nodorum blotch pathotypes to breeders and researchers, the project is also ensuring selection of relevant disease resistant varieties for Australian growers.

With reports of increased frequency of new pathotypes observed for net blotches of barley, the research team is turning its attention to working towards understanding the mechanisms of infection by barley spot-form net blotch and net-form net blotch. Knowledge obtained will help to identify key molecular determinants in net blotch pathogens that underlie pathogenicity and host adaptation.

This project is funded by the Grains Research and Development Corporation.



Theme C: Canola and Pulse Diseases

Lars Kamphuis

Theme Leader

Associate Professor

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In this research area, CCDM researchers focus on sclerotinia stem rot in canola and pulses as well as ascochyta blight in pulses. With a well-established track record of lab and field-based research that's had high impact in improving break crop profitability, this research team continues to deliver outcomes that ensure growers have more options to choose for their rotation systems.

Sclerotinia stem rot has a broad host range, is able to infect canola and other broad leaf crops grown in rotation (for example chickpea, faba bean, field pea, lupin), pasture legumes and even some weeds. For this reason, crop rotation does not help, and disease control relies heavily on timely fungicide applications. To combat sclerotinia disease, this research area aims to discover more sources of resistance, with the hope to apply these sources of resistance to hybrid and open pollinated breeding programs aided by a genomic prediction model developed at CCDM.

Ascochyta blight is also wreaking havoc in pulse systems. As an example, unprotected chickpea crops can lose more than 50 per cent in yield to diseases, with strong evidence indicating host resistance is eroding. To combat ascochyta blight of chickpea and lentils, it is vital CCDM research continues to discover sources of resistance, as well as monitor the landscape for changes in pathogen aggressiveness or a breakdown of resistance in the current varieties.



CCDM researcher and Theme C leader Lars Kamphuis

Theme C Projects	Funding body
Sclerotinia stem rot of canola and pulses	GRDC (CUR00023)
Ascochyta blight of chickpea and lentil	GRDC (CUR00023)
Disease screening and diagnostics to identify fungal pathogens impacting safflower in WA	GRDC (CUR2211-003RTX)
Towards effective genetic and sustainable management of ascochyta blight of chickpea – a GRDC-funded ICARDA led project	GRDC (ICA2007-001RTX)
Investigating Bioclay™ for sclerotinia management in canola	ARC Research Hub for Sustainable Crop Protection
Sclerotinia management for narrow leaf lupin crop in WA farming systems – a GRDC-funded DPIRD led project	GRDC (DAW2104-002RTX)
Increasing stable lupin productivity through enhanced disease resistances – A GRDC-funded DPIRD led project	GRDC (DAW2305-006RTX)

Sclerotinia stem rot of canola: Promising lines and field trial methods to improve variety resistance

CCDM project team: Mark Derbyshire (Project Leader), Lars Kamphuis, Sarita Bennett, Pippa Michael, Ashmita Rijal Lamicchane, Toby Newman and Yuphin Khentry.

Key points

- Through co-innovation with canola breeders, this team have developed research priorities that target the industry demand for disease resistant varieties.
- The team have delivered five promising sclerotinia stem rot resistant canola lines to Australian breeders to help bring sclerotinia resistant canola to the market.
- In-field disease infections have always been a challenge, however the team overcame this by developing a new and successful protocol for field trial infections.

Sclerotinia stem rot is a significant crop disease threat to canola production in Australia, causing up to 10 per cent per year in average yield losses. Furthermore, resistant varieties are not available in Australia, and so the disease is mainly managed through fungicide application.

Fortunately, this project has discovered new candidate sclerotinia stem rot resistant lines that can be used by Australian canola breeders to help bring sclerotinia stem rot resistance to market. By conducting several glasshouse, controlled environment and field screens, the research team were able to precisely assess the levels of resistance in several of the most promising lines. They were able to find five canola lines with significantly smaller stem lesions than the three Australian cultivars Bonito, Mako and Stingray after 21 days of infection.

The relatively high level of resistance in these five lines was not influenced by pathogen isolate, which is highly promising for breeders. The two lines Chikuzen and Chisaya were of particular interest to breeders because they were among several lines used as sources of blackleg resistance in the public breeding programmes of the 1980s. The lines are freely available to breeders through the Australian Grains Genebank.



CCDM researchers Mark Derbyshire and Sarita Bennett working on sclerotinia stem rot

This project has also been able to improve field trial methodology – a research priority established by canola breeders. By discovering a new and successful way to infect canola plants in the field with the disease, the team have been able to help breeding companies assess canola resistance through field trials, rather than in a glasshouse or controlled environment that may not be representative of field conditions. Recently developing a protocol for producing powdered red rice carrying fungal tissue, the team demonstrated consistent infections in an irrigated plot at Curtin, with no additional infrastructure required.

Overall, this research has delivered solutions to key research gaps identified by canola breeders, which could help them tackle this challenging disease issue.

This project is funded by the Grains Research and Development Corporation.



Apothecia of *Sclerotinia sclerotiorum*



CCDM researchers Pippa Michael and Ashmita Rijal Lamicchane planting canola in CCDM's Field Trial Area



CCDM researchers Toby Newman and Mark Derbyshire collecting canola leaves



CCDM researchers Yuphin Khentry and Toby Newman working with arabidopsis plants

Ascochyta blight of pulses: Decision support tools and sources of resistance for lentil and chickpea growers

CCDM project team: Lars Kamphuis (Project Leader), Robert Lee, Bernadette Henares, Christy Grime, Hedyeh Tahghighi, Johannes Debler, Emma Thackwray, Jessa Mae Barron and Grace Foley.

Key points

- Growers can now decide which lentil variety is best suited to their paddock, through a laboratory-based diagnostic *Ascochyta lentis* pathotype toolkit.
- The discovery of Quantitative Trait Loci (QTLs) and markers associated with resistance in lentils have been deployed in lentil breeding programs to improve disease resistance.
- Monitoring of ascochyta blight affecting both chickpea and lentil on an annual basis has meant industry is up to date with any pathotype changes.

Ascochyta blight is a devastating fungal disease affecting pulse crops of Australia. To be one step ahead of this disease, this research team continuously monitors for changes in aggressiveness and pathogenicity on current varieties of chickpeas and lentils, so that growers can be prepared and have the solutions they need when managing outbreaks. By collecting isolates of *Ascochyta lentis* (affecting lentils) and *Ascochyta rabiei* (affecting chickpeas) on an annual basis, the research team are ensuring the industry is up to date with any changes.

The research team identified sources of ascochyta blight resistance in chickpeas and lentils and identified Quantitative Trait Loci (QTLs) associated with the resistance in lentils using seedling assays. The sources are deployed by lentil breeding programs and markers associated with the QTLs can now be implemented or identified as associated with ascochyta blight resistance on the pulse SNP chip. This is encouraging news for growers, as this can lead to future varieties with improved ascochyta blight resistance.

Following the discovery of an avirulent effector responsible for triggering a defence response in lentils, the team of researchers have delivered a diagnostic



CCDM researchers Hedyeh Tahghighi and Johannes Debler analysing ascochyta blight in lentils



Chickpea infected with ascochyta blight



CCDM and DPIRD researchers meet with Esperance lentil grower to discuss disease management

A. lentis pathotype toolkit to the grains industry, where growers can send in samples to CCDM, and a simple lab test can be carried out to distinguish and quantitate the levels of the two different pathotypes for the species present in their sample. The high throughput laboratory-based test can now be implemented as a decision support tool for lentil growers or optimised to be deployed in the field. The team is seeking expressions of interest from lentil growers to utilise and adopt the test.

The major impact of the lentil-ascochyta blight research at CCDM has seen breeders have access to new resistant germplasm and has allowed growers to decide which variety is best suited to their paddock. The lentil-ascochyta blight decision support tool enables growers to make the right decision for the next season to ensure reduced ascochyta blight on their lentil crop, improving the overall profitability of pulse crops and making them a viable option in the rotation.

This project is funded by the Grains Research and Development Corporation.



CCDM researcher Hedyeh Tahghighi



CCDM researchers Lars Kamphuis, Robert Lee and Bernadette Henares with their lentil experiment

Towards effective genetic and sustainable management of ascochyta blight of chickpea

CCDM project team: Lars Kamphuis (Project Leader), Robert Lee and Bethany Clark.

Collaborators: International Center for Agricultural Research in the Dry Areas (ICARDA).

Key points

- Genome assemblies were generated for 13 international isolates and 12 Australian isolates of chickpea pathogen *Ascochyta rabiei*, to help discover candidate pathogenicity genes.
- A whole genome phylogenetic comparison revealed all Australian isolates cluster together and have small levels of genetic diversity relative to the international isolates.
- By the end of this project, chickpea breeders will have access to novel ascochyta blight resistant genes to generate chickpea resistant varieties.

This GRDC-funded project led out of ICARDA aims to develop a differential set of chickpea lines with known markers associated with each resistant gene and associated ascochyta blight pathotype structure with the corresponding (A)virulence genes. As part of this project, CCDM researchers have developed segregating fungal populations of *Ascochyta rabiei* – the pathogen causing ascochyta blight in chickpea – to aid the (A)virulence gene discovery and determine the pathotype structure for the species.

The research team generated the genome assemblies for 13 international isolates and 12 Australian isolates, to help aid the discovery of candidate genes that underlie Quantitative Trait Loci (QTLs) associated with pathogenicity of the different *A. rabiei* isolates. Using high molecular weight DNA extraction protocols followed by Oxford Nanopore long read sequencing, the team found that the 13 international isolates' genomes do not vary significantly in size or gene content compared to Australian isolates. However, a whole genome phylogenetic comparison revealed that all Australian isolates cluster together and have small levels of genetic diversity relative to the international isolates (figure 4). This finding supports previous findings by CCDM that indicate that there is more diversity in sexual international isolates compared to the clonal Australian isolates.

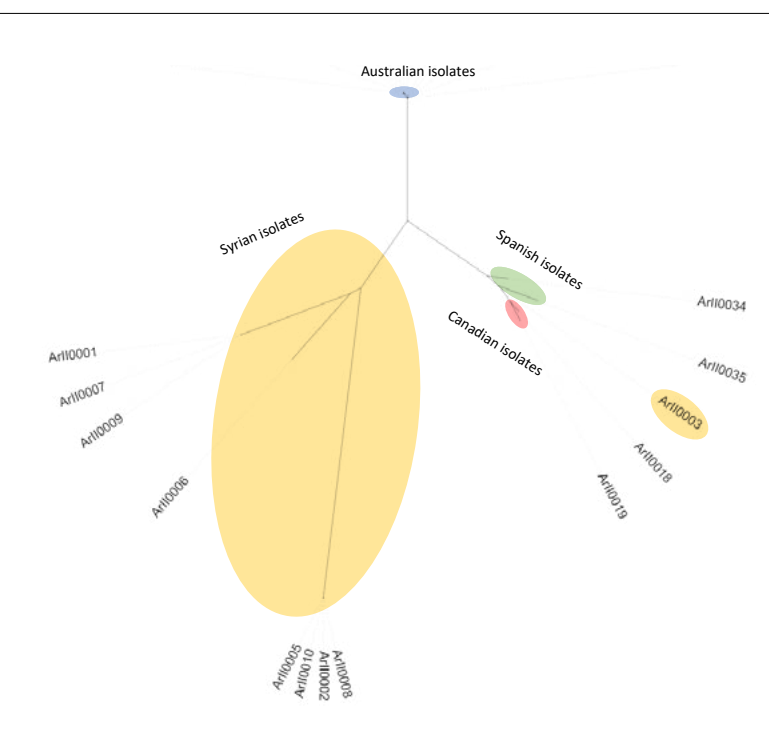


Figure 4. Whole genome phylogenetic relationship of 12 Australian and 13 international isolates sequenced to date. The 12 Australian isolates all cluster together and have a narrow genetic diversity when compared to the international isolates



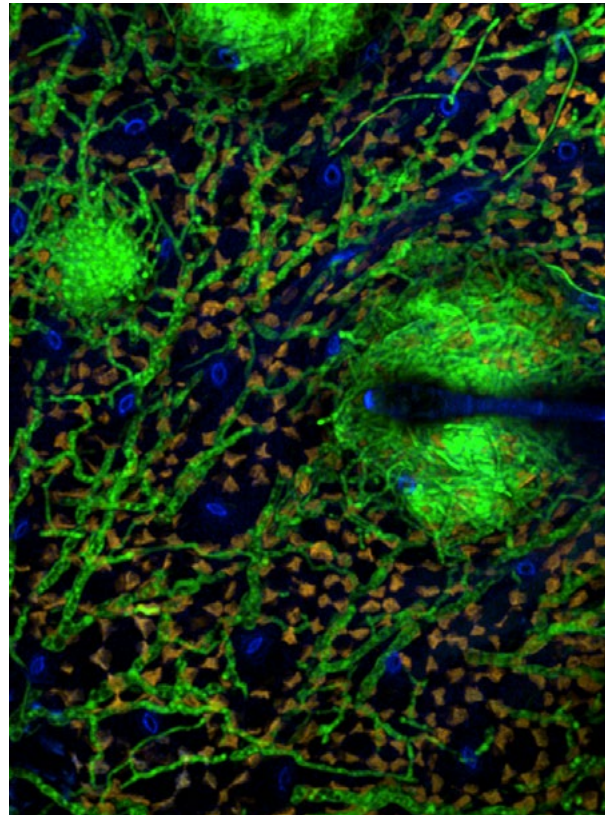
CCDM researcher Bethany Clark demonstrating Oxford Nanopore long read sequencing research to visitors

By the end of this project, the Australian and overseas chickpea breeders and pre-breeders will be able to access novel ascochyta blight resistant genes available in the chickpea germplasm to generate future varieties with improved durable ascochyta blight resistance, and be able to understand which of these sources can be deployed based on the pathotype structure and (A) virulence genes discovered. Combined, these outputs will enable the chickpea growers in Australia and abroad to improve their production and profitability.

This project is funded by the Grains Research and Development Corporation.



CCDM researcher Bethany Clark



Ascochyta rabiei growing on a chickpea leaf under a confocal microscope



Ascochyta blight on chickpea

Investigating Bioclay™: Using RNAi as an alternative way to control sclerotinia

CCDM project team: Lars Kamphuis (Project Leader), Mark Fisher and Thomas Hill.

Collaborators: ARC Hub for Sustainable Crop Protection.

Key points

- Through CCDM's capacity to test blue-sky ideas and a collaboration with the ARC Hub for Sustainable Crop Protection, RNA interference (RNAi) was tested as a potential new non-chemical way to manage disease outbreaks.
- No significant differences were observed between the control and the 40 small scale double-stranded RNA (dsRNA) constructs that targeted 40 pathogenicity genes.
- The current findings from this research suggest that using dsRNA to effectively control sclerotinia in canola is unlikely.
- Protocols have been developed to effectively screen the effect of double-stranded RNA (dsRNA) constructs on fungal growth and pathogenicity.

As cases of fungicide resistant pathogens continue to rise across the Australian grains industry, the need for new non-chemical management options to control disease outbreaks has never been more important.

Within the ARC Hub for Sustainable Crop Protection, this research team has looked beyond chemical fungicides to find a novel strategy to help control the pathogen *Sclerotinia sclerotiorum* that causes sclerotinia stem rot in canola and pulses. By using RNA interference (RNAi), the team have tried to design double-stranded RNA (dsRNA) constructs to target pathogenicity genes, in the hope of applying these dsRNA molecules encapsulated in nanoparticles called BioClay™ to silence these genes.

To design the dsRNA, a total of 40 small scale dsRNA constructs were synthesised, targeting 40 different pathogen genes at a small scale for *in vitro* and detached leaf assays. Unfortunately, no significant differences were observed between the control and the treated samples. The team then obtained mid and large-scale dsRNA batches targeting three genes previously demonstrated in the literature as giving a phenotype, using detached leaf assays (DLAs) and glasshouse and controlled environment rooms, yet still there were no significant differences observed relative to the no treatment control.

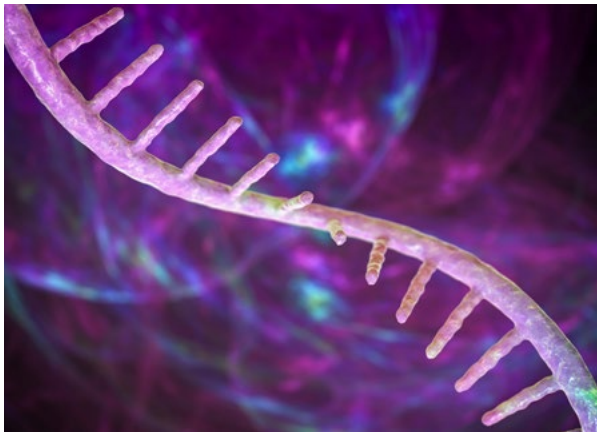
Subsequently, the team focused on developing phenotyping assays using *S. sclerotiorum* ascospores rather than agar plugs. This method has some promise and will be further developed in 2024. However, given



CCDM researcher Mark Fisher and CCDM student Thomas Hill researching alternative ways to manage sclerotinia stem rot

the current findings, the research team believe using dsRNA to effectively control sclerotinia in canola is unlikely. Nevertheless, this research is a good example of CCDM's ability to test new, blue-sky ideas to find solutions to the many challenging problems of crop disease. Furthermore, the protocols developed in this project are now being applied to test if dsRNA can be an effective means to control ascochyta blight in pulses.

This research was funded by the Australian Research Council.



Molecular model of mRNA, computer illustration



Under the canopy of a canola crop



Sclerotinia stem rot infecting canola



CCDM researcher Lars Kamphuis

Improving sclerotinia management in lupins for WA farming systems

CCDM project team: Sarita Bennett (Project Leader), Pippa Michael, Lars Kamphuis, Rachael Crockett and Ashmita Rijal Lamichhane.

Collaborators: Department of Primary Industries and Regional Development (DPIRD).

Key points

- This research has significantly improved understanding of the disease epidemiology of sclerotinia infection in lupins.
- Susceptibility to the disease was confirmed in three commonly grown lupin varieties. Furthermore, significant differences in aggressiveness were confirmed between WA isolates *Sclerotinia sclerotiorum*, highlighting the need to test a wider range of varieties.
- With enhanced knowledge on disease management strategies for lupins, this research has improved break crop options for growers.

Since 2015, there have been widespread reports of sclerotinia stem rot affecting lupin crops across WA. While management strategies for sclerotinia in canola and other pulse crops have been widely studied, there is little information available on the management of the disease in lupins. Furthermore, the lack of registered fungicides leaves growers with few options to manage the disease.

This research team successfully inoculated albus and narrow leaf lupins with *Sclerotinia sclerotiorum* isolates and found all three lupin varieties were susceptible to the disease. They also found that lupin response to each isolate was variable, and that several local isolates appeared to be more aggressive than others plus had a greater impact on seed production, as well as producing more sclerotia following infection. From these important findings, a greater range of varieties will be tested for resistance in the field as part of a project funded by the WA Agricultural Research Collaboration (WAARC) and GRDC in 2024.



CCDM researchers Sarita Bennett and Rachael Crockett with their lupin experiment



Lupins varieties grown in WA are highly susceptible to sclerotinia stem rot

The team also explored fungicide management strategies for lupins, and confirmed that application of Orius and Prosaro at the recommended rate would inhibit actively growing mycelium, but Mirador would not. Furthermore, 11 of their reference sclerotinia isolates showed susceptibility to all fungicides in a similar range.

A major outcome of this project was the development of a method to infect lupins in the field by using powdered organic inoculum, to better mimic natural infection in farming systems. This method worked well in the glasshouse for lupins, has been successfully tested in canola in the field and is being refined for infection in lupins in the field within the WAARC project for 2024.

Because of this research, there is now a much better understanding of the disease epidemiology of *Sclerotinia sclerotiorum* and its infection in lupins. The research has improved knowledge around the best management strategies for sclerotinia stem rot in lupins, ensuring this crop remains a viable option as a break crop in rotation systems for the future.

This project is funded by the Grains Research and Development Corporation.



CCDM researcher Pippa Michael in the field



Sclerotinia stem rot infecting a narrow leaf lupin plant

Safflower diseases: Solving the disease mystery in WA Safflower trials

CCDM project team: Lars Kamphuis (Project Leader), Julia Easton, Mark Gibberd and Azin Moslemi.

Key points

- CCDM has demonstrated an exceptional ability to immediately respond to industry needs, with the rapid identification of a mystery disease affecting safflower crops in WA.
- Further to identifying the pathogens responsible, the team were also able to confirm grain contamination as the likely source of infection.
- This information has allowed safflower growers to be informed on the implications of the disease and make the necessary decisions to ensure productivity.

Safflower has potential as a break crop for Western Australian growers and when reports of moderate to severe levels of mystery diseases in the 2022 growing season reached CCDM, the project team responded immediately. By leveraging skills obtained in other CCDM projects and rapidly deploying them to find out the causal diseases, this GRDC-funded project represents CCDM's ability to work with industry in a timely manner to inform growers of the implications of the disease and make the necessary decisions to ensure productivity.

To find the causal agents of the disease, the team worked together with the breeding program,

agronomists and growers to sample diseased plants from 15 different sites across WA and establish an isolate collection of 334 isolates. Morphological and molecular diagnostics on these isolates using three conserved genomic regions identified the predominant genus to be *Alternaria* (77%), and the second most predominant genus was *Stemphylium* (19%). Subsequently, Koch's postulates were performed to narrow down the causal pathogens to *Alternaria alternata* and *Stemphylium eturmiunum* as the reason for the disease symptoms in the 2022 safflower crops. The pathogens are not new to WA.

Additionally, the project team were able to confirm that grain contamination occurs with these two pathogens and could represent a source of infection. They could also confirm that none of the other minor pathogens identified in the diagnostic tests represent new diseases previously unknown in WA.

This project is now complete, however further work is required to develop seed contamination tests and the role of the other pathogens identified in the disease symptoms observed in the 2022 growing season. Optimising the conditions for inoculation with the various pathogens in future research would also allow the evaluation of safflower germplasm for sources of resistance.

This project is funded by the Grains Research and Development Corporation.



CCDM researcher Julia Easton in a safflower crop



Flowering safflower



Foundation Projects

Mark Gibberd

Theme Leader
CCDM Director
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The CCDM foundation projects underpin new or emerging areas of research and directly support and complement the core science within CCDM's three major research areas (fungicide resistance, cereal diseases and canola and pulse diseases) by developing foundational tools and capabilities.

They leverage opportunities with non-traditional partners and play important roles in the delivery of research outputs from across the CCDM to industry. CCDM currently has five foundation projects funded by GRDC, plus a number of other projects from other funding sources.



CCDM Director Mark Gibberd addressing a WA grower group

Foundation Projects	Funding body
Impact, economics and engagement	GRDC (CUR00023)
Plant physiological responses to fungal diseases	GRDC (CUR00023)
Fungicide dynamics	GRDC (CUR00023)
Effector and co-infection biology	GRDC (CUR00023)
Advanced bioinformatic approaches	GRDC (CUR00023)
Industry Studentship	InterGrain
Data Partnerships Initiative	GRDC (CUR2206-001SAX)

Economic analysis on survey data for improved extension

CCDM project team: Mark Gibberd (Project Leader), Toto Olita, Megan Jones and Lisa Smith.

Collaborators: Billy Sung and Michelle Stankovic from Curtin Business School.

Key points

- Using qualitative data collected from phone conversations with 137 growers, the research team confirmed how growers seek and use information on fungicide resistance. Growers prefer advice suited to their local context and from trusted experts.
- The findings have important implications for extension, highlighting the need for initiatives that facilitate communication between agronomists and growers.
- By ensuring extension activities are timely, relevant, accessible and tailored, growers will feel more empowered to make well-informed crop protection decisions, leading to positive practice change.

By applying economic analysis to CCDM discoveries and extending research outputs to growers and advisors, CCDM has ensured discoveries are reducing the economic impact of crop disease. In this project, the research team is constantly applying economic data analysis to all other CCDM research areas including fungicide resistance extension.

Using qualitative data collected from phone conversations with 137 growers, this project has improved the industry's understanding of how growers in the Southwest Western Australian wheatbelt access information and resources to manage fungicide resistance. The team found that growers seek information from trusted experts who can simplify complex research. They also found that growers value easy-to-understand communication and prefer resources tailored to their local context. Additionally, growers valued information regarding new fungicide developments and having access to rapid fungicide resistance diagnostic services. Growers expressed concerns about their lack of preparedness in responding to emerging threats posed by fungicide resistance. They often felt disadvantaged and unable to adequately prepare for new infections due to the scarcity of resources dedicated to addressing fungicide resistance challenges.

The findings have important implications for extension as they highlight the importance of supporting initiatives that facilitate effective communication between agronomists



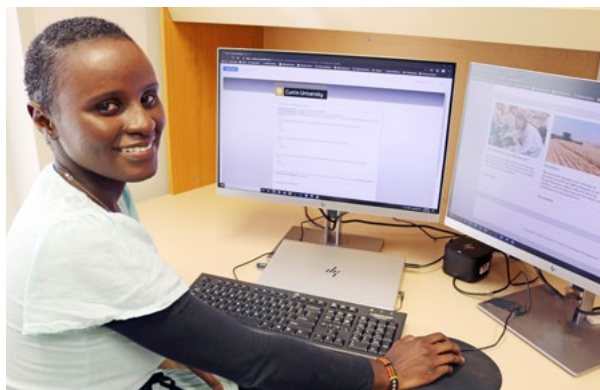
WANTFA CEO David Minkey (left) and CCDM Director Mark Gibberd (right) assess field trials in the WA Wheatbelt

and growers. There is a need for timely and relevant fungicide resistance management information that aligns with growers' preferences and operational constraints. In prioritising accessible and tailored communication strategies, extension services can effectively disseminate information on fungicide resistance management. This has led to empowering growers with the insights required for sustainable and informed decision-making, leading to positive practice change across the Australian grains industry.

This project is funded by the Grains Research and Development Corporation.



CCDM survey found growers seek information from trusted experts



CCDM researcher Toto Olita



Sprayer used to apply chemicals such as fungicides on farm



CCDM's Megan Jones addresses a grower group about a fungicide resistance project

Plant physiological responses: Measuring responses to disease to explore new breeding targets

CCDM project team: Fatima Naim (Project Leader), Mark Gibberd, Lilian Sanglard and Sabrina Cuellar.

Key points

- CCDM has delved deeper into how plants tolerate and recover from disease, and it is on the path to finding alternative and additive traits to breed more resilient crop varieties.
- This project showed the first application of synchrotron microscopy to dissect disease impact on plants.
- With a combinatorial application of synchrotron microscopy and spatially resolved molecular analysis, the research team have discovered that calcium is re-distributed in a way that is dependent on the environment and pathogen load.

While significant progress has already been made to identify disease resistance traits in plants, little is known about how plants tolerate disease and recover efficiently post-disease infection, and how this recovery impacts yield potential. This CCDM project has made significant headway towards developing a new generation of breeding targets beyond the traditional effector-receptor interaction discoveries, as an alternative way to breed crop varieties with improved resistance.

By assessing the progression of yellow spot disease in wheat, analysis has shown that calcium is uniquely manipulated in susceptible wheat, and the asymptomatic regions surrounding the lesions are desensitised to follow-up infection. A follow-up comparison of calcium re-distribution in four wheat genotypes infected with yellow spot disease found that the re-distribution of calcium is dependent on how the disease develops based on the environment and pathogen load. It is also independent of the major susceptibility gene (*Tsn1*) described in wheat that interacts with a major toxin of the pathogen causing yellow spot disease.

To further characterise this phenotype, the team investigated the potential for other interactions between the host that the pathogen can manipulate or deploy



CCDM Director Mark Gibberd and CCDM researcher Fatima Naim



Yellow spot on wheat

resulting in the observed disease phenotypes. For this, a large wheat experiment was set-up in the glasshouse in collaboration with the Analytics for the Australian Grains Industry (AAGI) initiative and the Department of Primary Industries and Regional Development (DPIRD). The molecular analysis was combined with high-resolution microscopy including X-ray fluorescence microscopy at the Australian synchrotron and confocal microscopy at Curtin's Bentley Campus to associate the mineral nutrient redistribution and fungal growth to develop pathways leading to disease resistance and susceptibility. The outcome of this layered approach is expected to generate novel insights into the genetics of the host that give rise to resistance and susceptibility.

With a demonstrated capacity to find genetic variation in non-traditional disease traits, the insights and techniques developed in this project have enabled CCDM to characterise localised plant responses to disease stress. This research team have created a foundation to advance knowledge of plant pathology and are on an upward trajectory to assess, characterise and identify key genes and pathways as alternative forms and added layers of defence in crop plants.

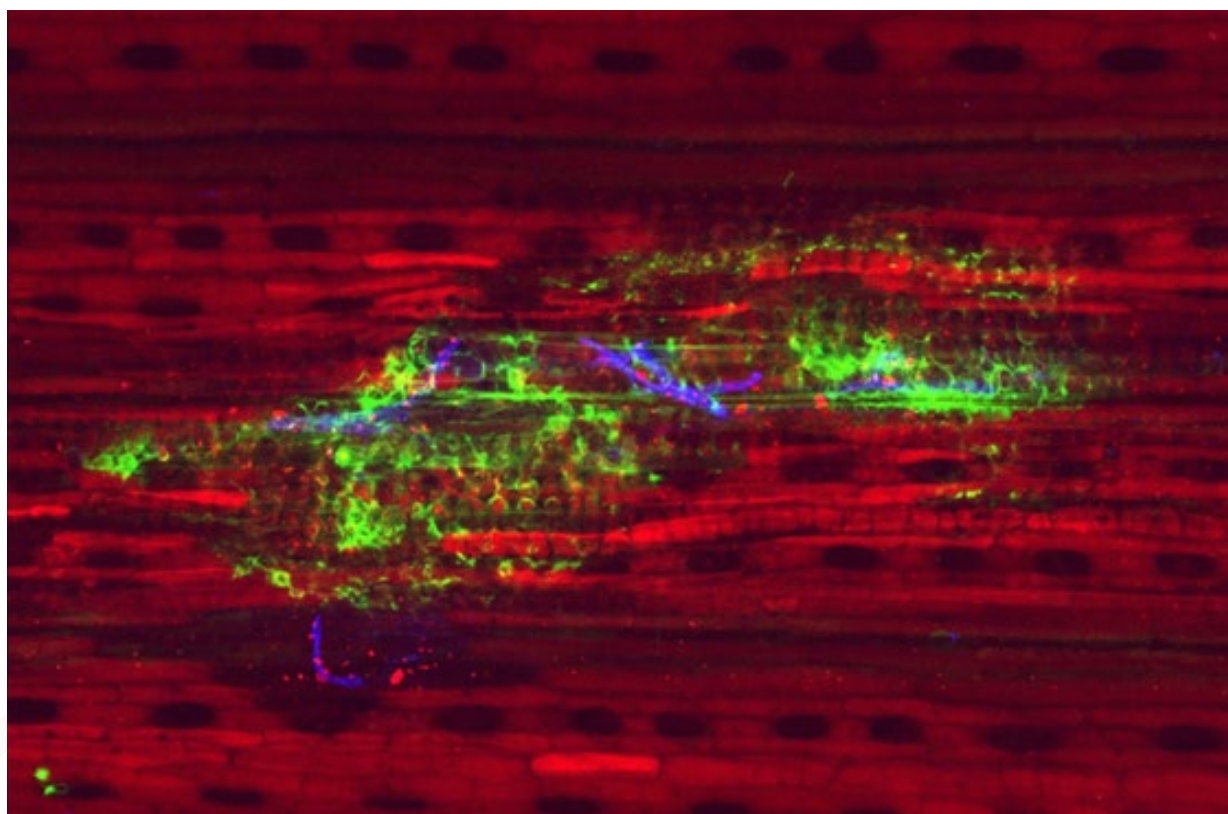
This project is funded by the Grains Research and Development Corporation.



CCDM student Daniel Yutathkarn shows his work to colleagues at Curtin's HIVE facility



CCDM researchers Lilian Sanglard and Fatima Naim



A high-resolution X-ray fluorescence microscopy (XFM) image of a resistant wheat leaf infected with yellow spot disease. The image shows the localised response of mesophyll cells to the fungal pathogen (traced with copper accumulation in blue) by the hyperaccumulation of manganese (green) and calcium distribution is shown in red. The XFM technique was optimised to capture images at cellular resolution.

Fungicide dynamics: Determining fungicide behaviour once in the crop

CCDM project team: Jordi Muria Gonzalez, Joshua Mylne, Jordan Campbell and Arundhati Singh.

Key points

- A library of known metabolites and fungicides has been successfully established to enable this project to measure fungicide distribution in crops.
- Preliminary research supports the dominance of fungicides' xylem mobility (from base to tip) over phloem mobility (from tip to base), and fungicide fluxapyroxad accumulates more in older leaves than in new ones.
- Research outcomes from this project will help growers with management decisions such as when to spray and what chemical to use to best protect their crops.

Despite the significant benefits fungicides offer to agriculture, there remains a knowledge gap regarding their lifespan within plants, metabolic pathways and the impact of environmental factors on biotransformation rates. This project has gained quantitative understanding on fungicide behaviour post-application, by developing methodologies for measuring fungicide distribution in crops.

The research team consulted with life science companies to establish the top 12 most appropriate commercial fungicides to study the general mobility of fungicide in plants. Preliminary results from experiments on fungicide mobility suggest that all 12 fungicides are xylem mobile (from base to tip) despite differences in rate among them, but none of them are showing significant phloem mobility (from tip to base).

A further three fungicides were selected for their economical and agricultural importance - azoxystrobin, metalaxyl-M and propiconazole – to establish a database of known metabolites and help build a library of known metabolites and fungicides. These three fungicides were also independently applied to seedlings of the model plant, *Arabidopsis thaliana*. Sample leaves were



CCDM researcher Jordi Muria Gonzalez

collected at different timepoints up to a month after treatment. Samples were processed and analysed by a liquid chromatography-mass spectrometer tandem system (LC-MS) for analysing small molecules in complex extracts, and were then compared against the generated library and database to identify fungicides and metabolites. All fungicides were detected but almost no metabolite was putatively identified nor confirmed by comparison to a standard.

Using the methods successfully developed from this experiment, the research team were able to take it a step further and study fluxapyroxad and how a seed treatment with fluxapyroxad moves within barley. The project was able to demonstrate that fluxapyroxad accumulates more in older leaves than in new ones and an uneven distribution within leaves, with fungicide concentrations up to 20 times higher in the tip of the leaves compared to the bottom part.

The next step is to understand how this distribution contributes to plant protection for enabling growers to make better decisions on how they use fungicide, leading to positive practice change across the grains industry. By establishing methodologies to detect and quantify in planta concentrations of fungicides, this project will help growers with management decisions such as when to spray and what chemical to use to best protect their crops.

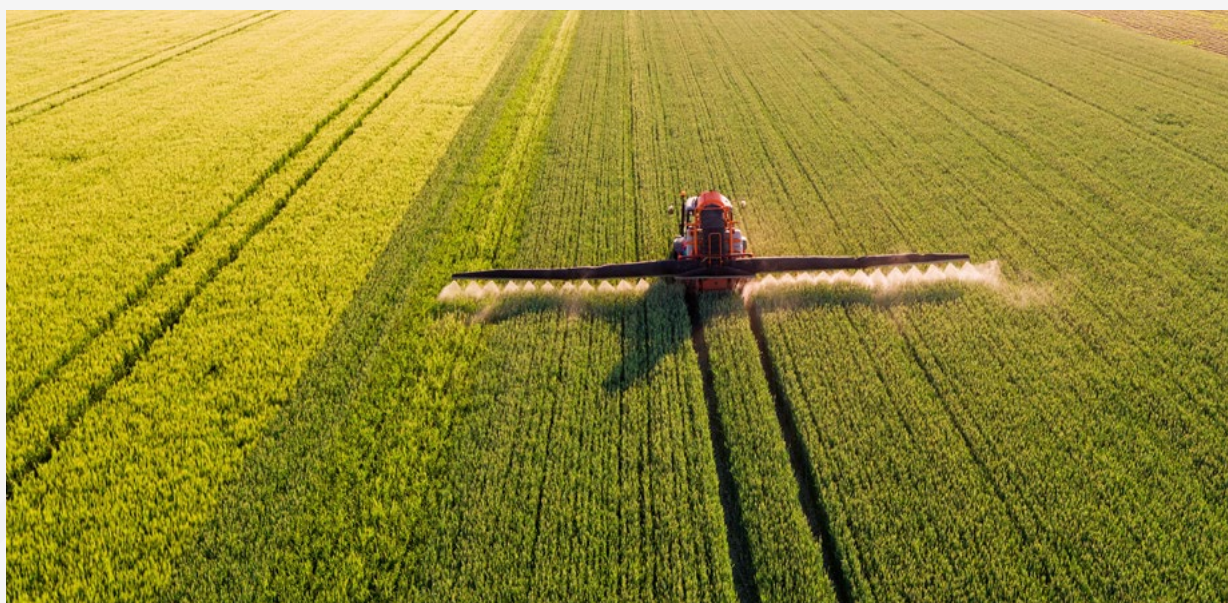
This project is funded by the Grains Research and Development Corporation.



CCDM student Arundhati Singh working on her fungicide experiment



CCDM students Varthini Govindaraju Punithan and Arundhati Singh with CCDM researcher Jordi Muria Gonzalez, using the Orbitrap Exploris 120 to study fungicide molecules in planta



Decisions around when to spray a crop and what chemical to use could be easier with the knowledge of in planta concentrations of fungicides

Effector and co-infection biology: Delving into effector regulation to determine how pathogens coordinate plant infection

CCDM project team: Kar-Chun Tan (Project Leader), Leon Lenzo, Callum Verdonk, Shota Morikawa, Ancy Tony, Anjana Sharma, Isobel Screiagh and Carlia Herbst.

Key points

- This project confirmed septoria nodorum blotch (SNB) of wheat in Australia is largely driven by necrotrophic effector Tox1.
- This finding has led to a clear picture of effector diversification and how easily a pathogen can overwhelm the plant defence by overproducing a necrotrophic effector.
- Functional validation and monitoring for effector expression variant pathogen population will provide breeders and growers with region-specific knowledge on which wheat varieties should be adopted.

Breeding for durable resistance to diseases is a continual challenge for crop breeders as fungal pathogens have developed many ways to overcome the crop's resistance. Association mapping is a method frequently used by researchers to seek out novel sources of genetic resistance, however, disease resistance quantitative trait loci (QTL) detected through association mapping are often minor and inconsistent across environments.

This is a particular problem with septoria nodorum blotch (SNB) of wheat caused by *Parastagonospora nodorum*. *P. nodorum* uses a suite of proteinaceous necrotrophic effectors (NEs) to cause necrosis on wheat carrying a matching dominant susceptibility gene. Interactions between these NEs are complex during infection. Once thought to quantitatively contribute to SNB, we now know that NEs mask each other's contribution.

This project is the first to identify differences in the expression of the Tox1 NE gene caused by a genetic polymorphism in the promoter. This increases the contribution of Tox1 to SNB as it masks the action of other NEs. We now know that SNB of wheat in Australia is largely driven Tox1. By focusing on the SNB pathogen, this finding has led to a clear picture of effector diversification and how easily a pathogen can overwhelm the plant defence by overproducing an NE.



CCDM researchers Shota Morikawa, Leon Lenzo and Kar-Chun Tan

Since the Tox1 promoter genetic polymorphism discovery, the research team have identified new regulatory components that control effector gene expression as well as other virulence factors in cereal infecting fungal pathogens.

The team are now investigating the functions of regulatory factors for their role in effector expression and virulence. Functional validation and monitoring for effector expression in fungal strains will provide breeders and growers with region-specific knowledge on how effector production is coordinated so that we can identify wheat varieties with maximal resistance to the local pathogen population with a defined effector profile.

In addition, this research team has a strong focus on identifying genetic mechanisms used by NEs to cause damage on wheat. For many years they have been studying the transcription factor called PnPf2, that directly regulates NE gene expression and virulence in SNB disease in wheat. The team is in the process of identifying a biological signal that switches on (or off) the expression of effector genes through PnPf2. Manipulation of such signals in the field will offer another avenue for enhanced crop resistance against necrotrophic fungal diseases. The team is close to validating the genetic switch on effector promoters for which PnPf2 binds and activates.

This project is funded by the Grains Research and Development Corporation.



Septoria nodorum blotch on wheat



Infiltrating a wheat leaf with effector proteins.



CCDM researcher Callum Verdonk

Bioinformatics: Using advanced bioinformatic approaches to show how pathogens infect crops

CCDM project leader: James Hane.

Collaborating organisations: BioPlatforms Australia Pathogen Omics Initiative.

Key points

- This project has delivered new capabilities in pangenomic crop disease diagnostics and surveillance, establishing low-cost innovative methodologies using pangenomic data, profiling effectors and fungicide resistance.
- One such method, *EffectorFisher*, is able to identify effectors strongly associated with host resistance/susceptibility receptors, reliably predicting cultivar-specificity of individual effectors/candidates, and overall cultivar disease score versus pathogen isolates.
- This method has been incorporated into a software toolkit and can be applicable to any fungal pathogen or crop, with broad potential benefits across the Australian grains industry.

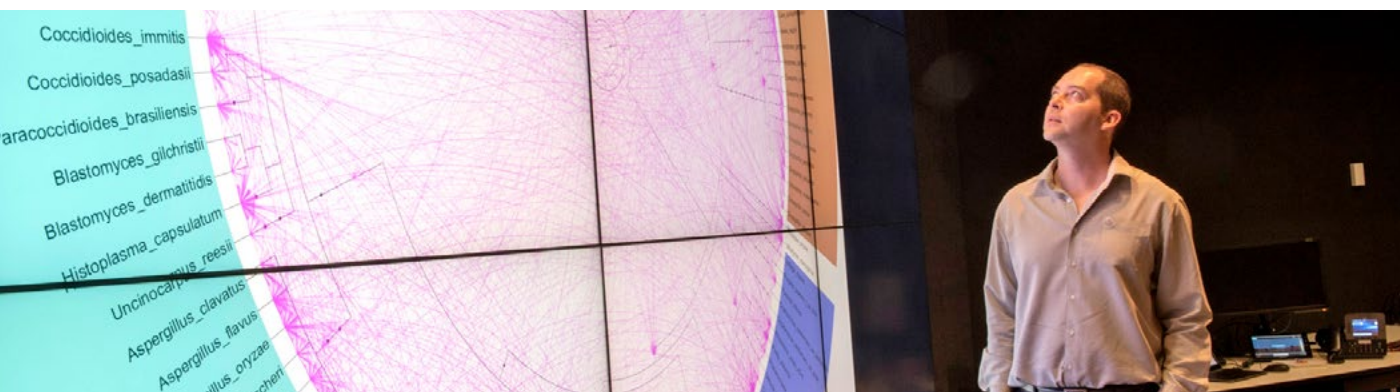
This project aims to improve fundamental knowledge of host-pathogen interactions, fungal genome biology, evolution of pathogenicity and effector biology, using cutting-edge bioinformatics approaches across all crop disease research areas. This project has delivered various new capabilities in 'pathogenomics', with a recent focus on pan-genome-based crop disease diagnostics and surveillance. These capabilities support accelerated

disease-resistance breeding, and enable efficient regional surveillance of fungicide-resistance and pathogenicity effector profiling at low cost.

This project is merging its new pan-genome effector screening and other past methods into a collective toolkit named *Myco-Management*, which includes the *fungicide resistance allele screening tool* (FRAST) which can automatically detect potential resistance mutations, and *EffectorFisher* which can generate accurate and cultivar-specific effector predictions based on protein isoform profiling and disease phenotype data. This research team also focuses on identifying novel effector features in order to further improve effector candidate prediction and validation, with a view to rapidly closing the gap in converting genome-based diagnostics into useful information for disease resistance pre-breeding.

The impact of this research can be seen from the wealth of pathogenicity-relevant data mined at low-cost assays from published and ongoing pan-genomic studies, which are capable of providing rich information on effector content, effector candidates, their predicted cultivar susceptibilities, fungicide resistance mutations, and genome adaptation potential (i.e. risk of future outbreaks). The methods developed by this research team can be applied to genome collections of high and low quality, including reference and draft quality genome data, and to studies with as few as >50 isolates with phenotyping on >2 cultivars. Because of this, these approaches are readily transferable to most fungal pathogen-crop systems, which this project is applying to alternative pathogens of importance to GRDC through collaboration across the BioPlatforms Australia Pathogen Omics Initiative.

This project is funded by the Grains Research and Development Corporation.



CCDM researcher James Hane with his bioinformatics work

Industry studentship: Developing genetic resistance to powdery mildew in wheat

CCDM project team: Ancy Tony (PhD student), Kar-Chun Tan, Simon Ellwood, Fran Lopez-Ruiz and Huyen Phan.

Collaborators: InterGrain (Dan Mullan), Sam Trengove (Trengove Consulting), Ben Saunders (Curtin University).

Key points

- CCDM partnered with InterGrain to support a PhD student to find new genetic tools that can be adopted by breeders for crop improvement against wheat powdery mildew (WPM).
- Virulence studies on Australian WPM isolates identified distinct Western and Eastern Australian pathotypes. The research has also revealed Western Australian isolates were significantly more aggressive than Eastern Australian isolates.
- Genetic and infection studies using wheat populations identified effective *R* genes with the potential to be deployed into future wheat varieties.



CCDM PhD student Ancy Tony working on wheat powdery mildew

CCDM will often establish partnerships with the grains industry to develop studentships to solve shared problems in crop disease research. In the case of the wheat powdery mildew (WPM) disease, CCDM partnered with InterGrain to offer a studentship to Ancy Tony, to delve into the pathogen and develop genetic tools that can be adopted by industry for crop improvement.

Working with her supervisors, Ancy pathotyped WPM isolates collected from across Australia from 2020 to 2022 and was able to determine the level of virulence using a wheat panel consisting of varieties with defined WPM resistance genes. As a result, the team observed multiple resistance genes with potential to be deployed into Australian commercial varieties for effective resistance to WPM.

The team then carried out non-metric multidimensional scaling of virulence scores to demonstrate evidence of distinct pathotypes present in Australia, and revealed Western Australian isolates were significantly more aggressive than Eastern Australian isolates.

In addition, preliminary evidence by the team has identified an *R* gene that is effective against a broad range of Australian powdery mildew pathogens.

The effective deployment of new resistance genes and knowledge of current pathotypes within this research project will support breeders in developing resistant varieties, which will lead to improved yield, higher quality grain, lower use of chemical controls and better market access.

This research is funded by InterGrain.



Wheat powdery mildew

Data Partnerships Initiative: Working together to make all data FAIR

CCDM project leader: Fatima Naim.

Collaborators: Curtin University Library.

Key points

- Curtin University is now part of a community of practice of 11 major GRDC research partners in data management.
- CCDM reported 31 metadata entries which were a compilation of data assets over 9 years, and worked with Curtin Library to create a custom online metadata form to report data outputs.
- This initiative has created a unified approach in making data findable, accessible, interoperable and reusable (FAIR) for better research outcomes for Australian grain growers.

Data generated from past GRDC investments is often hard to find and can often be unnecessarily duplicated or lost. To make data findable, accessible, interoperable and reusable (FAIR), Curtin has participated in the Data Partnerships

Initiative, a GRDC initiative that brought together a community of practice of 11 major GRDC research partners across Australia in data management.

The project is now complete, as the community of practice is now established with two streams of activity finalised from the initiative. The first was to locate and catalogue valuable data from the last ten years through GRDC investments. In this activity, CCDM was able to report 31 metadata entries which were a compilation of data assets generated by CCDM researchers over 9 years.

The second activity was to implement data governance, storage, standards, data vocabularies and data access for historical, current, and future data sets. Curtin assisted with the organisational alignment with GRDC requirements, and the Curtin Library created a custom online metadata form to report data outputs that were generated from GRDC investments at Curtin and are subsequently deposited in the Curtin and GRDC data catalogues.

Through the data partnerships initiative's reported metadata entries, the new GRDC Data Catalogue was populated with historic data assets and is now serving as a central mechanism for increasing the visibility of GRDC co-owned data sets. Overall, this initiative has seen a significant improvement in how GRDC and its partners manage RD&E data, ensuring a unified approach in making data FAIR for better research outcomes for Australian grain growers.

This project is funded by the Grains Research and Development Corporation.



CCDM researcher Fatima Naim led Curtin's involvement in the Data Partnerships Initiative

Curtin Biometry and Agricultural Data Analytics



CBADA Leader

Mark Gibberd

CCDM Director

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AAGI Technical Lead

Adam Sparks

Professor

Email: adam.sparks@curtin.edu.au



C4AP Group Leader

Julia Easton

Senior Research Fellow

Email: julia.easton@curtin.edu.au

CBADA brings together analytics research capabilities from across Curtin to focus on research outputs for the Australian grains industry.

With more than 30 researchers from three schools and two faculties across Curtin, CBADA already has a long and credible track records for delivering demand-driven research projects relating to agribusiness supply chains.

The initiative brings the biometry, bioinformatics and spatial data analytics capabilities from within CCDM together with spatial modelling and machine learning, computer vision and artificial intelligence, data security and data integrity, econometrics and optimisation from other schools and areas within Curtin.

There are two major components making up CBADA. These are:

- Analytics for the Australian Grains Industry (AAGI) – A GRDC initiative.
- Curtin for Agribusiness Profitability (C4AP) – a CCDM initiative.



**Curtin Biometry and
Agricultural Data Analytics**



AAGI: A new direction towards data analytics research

Adam Sparks

AAGI Technical Lead

Professor

Email: adam.sparks@curtin.edu.au

CCDM project team: Adam Sparks (Technical Lead), Mark Gibberd (Project Leader), Julia Easton, Suman Rakshit, Kefei Chen, Zhanglong Cao, Kristina Gagalova, Irena Kuznetsova, Jordan Brown, Rose Megirian and Mathew Nguyen.

Key points

- Through the new AAGI initiative, CCDM researchers are building on research outcomes from the completed Statistics for the Australian Grains Industry – West (SAGI West) project.
- AAGI at CCDM is already working on more than 70 high-impact research activities in partnership with other research organisations and relevant stakeholders.
- Projects range from core biometry services through to optimal experimental designs, advancing bioinformatics tools, fungicide resistance visualisation maps and more.

A newly launched initiative in 2023 has allowed Australian growers to have an opportunity to be world leaders in analytics-driven decision making, and CCDM has already begun research activities to help them achieve this.

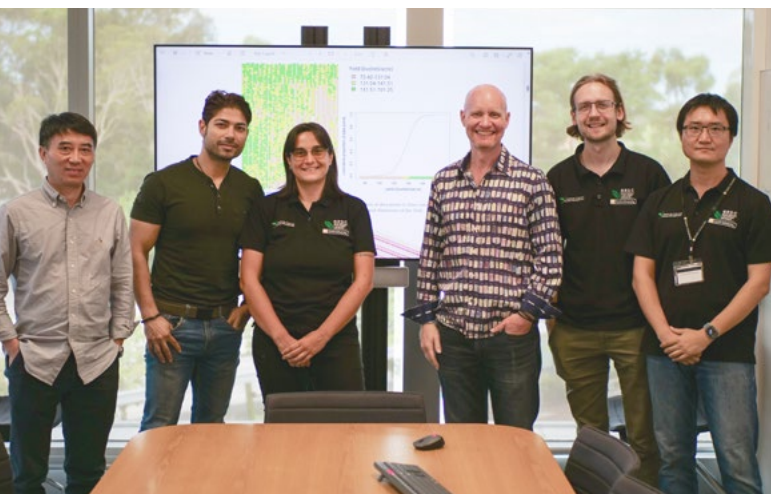
The Analytics for the Australian Grains Industry (AAGI) is a GRDC investment and is led by three strategic partners Curtin University, the University of Adelaide and the University of Queensland. Within the Curtin University part of the initiative, CCDM researchers continue to deliver core biometry services and research carried over from the completed Statistics for the Australian Grains Industry – West (SAGI West) project and are building on this foundation through new research activities that unleash the potential of statistics, machine learning, data fusion and analytics for Australian grain growers. AAGI at CCDM is already working on more than 70 high-impact research activities in partnership with other research organisations and relevant stakeholders.

Developing new statistical methods for analysing paddock-scale soil amelioration

Curtin is leading the first research and development project within the AAGI program, developing robust analysis for soil research investments and simple economic analysis (gross margin) of soil amelioration treatments. The research leverages the Food Agility CRC's Agri Analytics Hub project, led by CCDM, and historical soil amelioration trials from GRDC investments with the Department of Primary Industries and Regional Development in soil reengineering. The AAGI team has developed categorical analysis methods for paddock scale analysis of categorical treatments.

Helping growers to better understand risk

RiskWi\$e is a five-year, \$30 million national initiative seeking to understand and improve the risk-reward outcomes for Australian grain growers by supporting grower on-farm decision-making.



CCDM researchers Kefei Chen, Suman Rakshit, Kristina Gagalova, Adam Sparks, Jordan Brown and Zhanglong Cao work on AAGI projects



CCDM researchers Jordan Brown, Kristina Galalova and Adam Sparks working together

AAGI has collaborated with CSIRO and grower groups from across the country involved in the participatory action research, supporting the design and analysis of strip trials to ensure national consistency. Bringing together world-leading statistical analysis from the AAGI team with data cleaning and visualisation pipelines from CCDM's Curtin for Agribusiness Profitability (C4AP) team, grower groups can maximise insights from these trials.

This collaboration has ensured national coherence and regional relevance, enhancing on-farm decision-making and helping growers better manage decision making, particularly fertiliser strategies, through a deeper understanding of upside and downside risks.

Developing genetic solutions for better crops

In collaboration with researchers at Murdoch University, DPIRD and CSIRO, AAGI was involved in projects that aim to understand the complex genetic basis and develop genetic solutions for agronomically important traits including yield, nitrogen use efficiency, abiotic stress tolerance and disease resistance traits in barley, wheat, chickpea and lupin.

AAGI provided support on optimal experimental designs with a large amount of genotypes arising from multiple environments over several growing seasons, and analytics support including spatial analysis, multi-environment trial (MET) analysis, quantitative trait locus (QTL) analysis and genome-wide association analysis (GWAS). This ensured both genetic and genotype-by-environment interaction effects were accurately assessed through appropriate experimental design and analytics approaches to avoid experimental and analytical biases resulting in misleading conclusions for cultivar selection, and to deliver more accurate genomic predictions and selections. This approach is helping researchers confidently identify key genes for agronomic traits, develop diagnostic molecular markers and select optimal parents to improve crop yield and desired quality traits.

A bioinformatics approach to improving disease resistance in wheat

AAGI collaborated with CCDM's cereal diseases team in employing advanced omics tools to explore resistance mechanisms in wheat and barley against the fungal diseases septoria nodorum blotch, yellow spot and net blotch, aiming to enhance crop resilience and improve agricultural productivity. Additionally, the team also collaborated with CCDM's plant physiology project to develop new research approaches for investigating the physiological impact of fungal crop diseases, focusing on foundational studies to strengthen crop resilience.

Introducing Adam Sparks to lead the CCDM side of AAGI

CCDM recently appointed Professor Adam Sparks, internationally renowned epidemiologist, modeller and data scientist to provide technical leadership for Curtin's involvement in the AAGI program.

Professor Sparks has an extensive research background. Before joining CCDM, he was a manager with the Department of Primary Industries and Regional Development (DPIRD), leading DPIRD's Systems Modelling team's work in ag systems modelling, climate and weather and biometry. Prior to being at DPIRD, he was an associate professor at the Centre for Crop Health at the University of Southern Queensland where he led research on sorghum, mungbean, chickpea and tropical rice pathology and disease modelling.

Within the AAGI program at CCDM, Professor Sparks now contributes leadership to the research team to carry out projects relating to biometry, sampling, experimental design, bioinformatics, spatial modelling, machine learning, computer vision, artificial intelligence, econometrics, optimisation and more.

He will work with a growing team of biometricians and data analysts to ensure CCDM research can help growers turn raw data into meaningful knowledge for improved profitability, bringing Australian agriculture to the future.

AAGI is supported by the Grains Research and Development Corporation.



CCDM researchers Adam Sparks, Zhanglong Cao and Suman Rakshit discuss AAGI results

SAGI West ends with all-round success

CCDM project team: Suman Rakshit (Project Leader in spatial data analysis), Kefei Chen (Project Leader in Bioinformatics & Statistical Genetics), Kai Bagley, Jordan Brown, Zhanglong Cao, Andrew Grose, Darcy Jones, Paula Moolhuijzen, Smaila Sanni, Joseph Sigar, Katia Stefanova and Mark Gibberd (Project Leader).

Key points

- SAGI West was a GRDC project led by CCDM that concluded in 2023, with all capabilities of statistical support rolled into the new Analytics for the Australian Grains Industry (AAGI) project.
- SAGI West provided WA-based GRDC research partners with experimental design, statistical analysis and consultancy, as well as carrying out research projects of their own.
- SAGI West successfully supported grower groups with field trial research, helping them to address the research question and have applicable results, while keeping it uncomplicated.

Statistics for the Australian Grains Industry – West (SAGI West) was a GRDC funded investment that concluded in 2023, after seven years of delivering statistical support for research/academic institutions, growers and other industry members managing a GRDC investment. SAGI West provided research partners with experimental design, statistical analysis and consultancy for any grains Research, Development and Extension domains, including crop protection, biosecurity and regulation, soils, nutrition, agronomy and farming systems, genetic and enabling technologies and grower extension. The research team also carried out multiple statistical research projects of their own. Existing SAGI West's capabilities have been rolled into the new Analytics for the Australian Grains Industry (AAGI) project.

Supporting GRDC projects with statistics

The following two projects are examples of support provided by SAGI West to GRDC investments.

1. Experimental design for fungicide resistance project

SAGI West collaborated with CCDM's Fungicide Resistance research team on a project that aimed to deliver improved strategies for the management of fungicide resistance in barley. The overarching goal of this project was to deliver data-informed recommendations on fungicide resistance status, prevention, and targeted management to growers, agronomists and life science companies. SAGI West consulted on experimental designs and sampling strategies to assess the difference between three fungicide treatments under spatially varying disease pressure in two large paddocks in WA. Additional data about different mutations were also analysed by the SAGI West team. This is an example of how biometricians at SAGI West have helped researchers achieve rigorous scientific results from field trials.

2. Grower group project gains support from SAGI West

SAGI West researchers worked with the Grower Group Alliance and five grower groups to help ensure robust trial designs for the project *Closing the Economic Yield Gap for Grain Legumes in Western Australia*. The team made sure to address the research question and meet growers' needs while maintaining simplicity of the final analysis. Small-plot and large strip trials were designed for each of the five WA grower groups involved.

Innovative Statistics Research

Research has always been an important component of the SAGI West project, with the publication of peer-reviewed journal articles ensuring that GRDC investments contribute to world-class research outcomes. The SAGI West team worked on a number of different projects



CCDM researchers Smaila Sanni, Andrew Grose, Zhanglong Cao and Suman Rakshit working on SAGI West projects

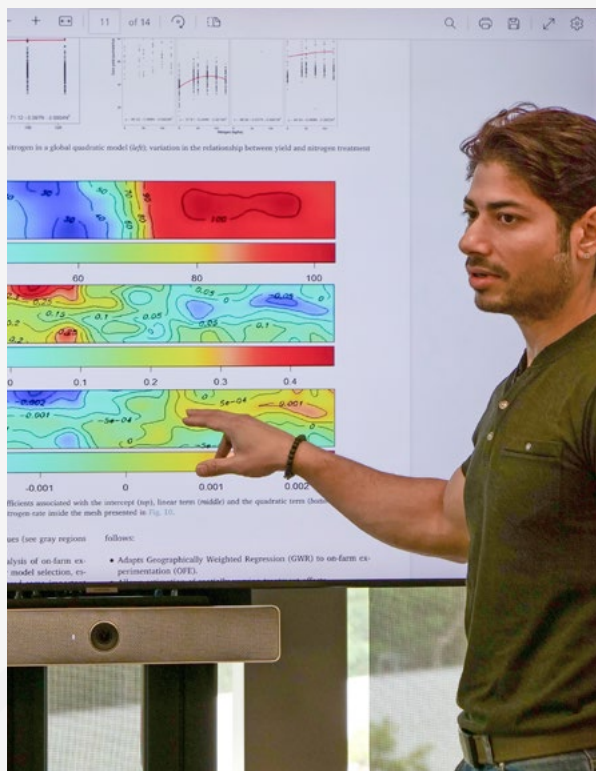
surrounding innovations in analytics. Such projects included:

- Assessing and comparing prominent statistical procedures for robust multivariate outlier detection.
- Assessing the role of spatial variability of treatment effects in the development of a management strategy that improves farms' profitability and sustainability.
- Providing efficient analytical approaches for accelerating gene discovery, trait dissection, and facilitating plant breeding based on high throughput and high dimensional data.

Statistics workshops in the Western Region

One of the primary aims of the SAGI West project was to raise statistical awareness in the grains research community and to expand on the level of statistical training that agricultural science graduates and statistical science graduates currently receive in their degree and higher degree programs.

The training program of SAGI West has been developed to address a wide range of audiences based on their



CCDM researcher Suman Rakshit presents SAGI research

knowledge in statistical science. Since the SAGI project begun in 2016, the training program has evolved and been well received by the grains research community across WA. All SAGI-West delivered training sessions were fully subscribed. In these sessions, participants were given the opportunity to work on real field experiment examples to practice their newly acquired statistics skills to obtain improved results from the analysis. Survey responses to the outcomes of training have always been very positive, with benefits to the GRDC research program and changes to work practices scoring highly.

SAGI Workshops

Do you carry out field research? Are you ready to improve the rigour of your work that helps growers improve productivity? Then it's time to get skilled in statistics and data analytics.

The SAGI-West team are calling for expressions of interest to run a statistics workshop in your region. From introductory to advanced, the statisticians will tailor the workshop to suit your level and requirements to run a field experiment which will ensure reliable results.

Introduction to Experimental Design & Data Analysis for Field Experiments

- Expand knowledge in the fundamentals of experimental design to ensure reliable results.
- Assess the suitability and have necessary knowledge to implement various designs in R using DLOGEST.
- Learn and apply reliable and efficient data management practices from design, data collection to statistical analysis.
- Know the procedure to fit a model in R based on the design.

Introductory R & Data Visualisation in R

- Provide strong foundation in the fundamentals of R programming using RStudio.
- Understand and improve skills in data management and manipulation.
- Produce dynamic reproducible reports with knitr and Rmarkdown.
- Create various plot types across graphical packages including graphics, lattice and ggplot2.

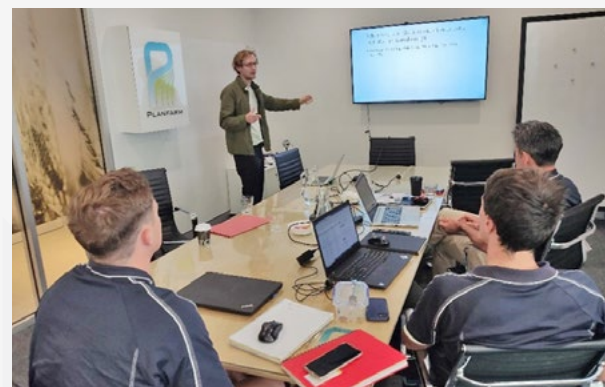
Advanced Theory & Application of Linear Mixed Models in Plant Research

- Review and extend knowledge in the theory and application in the context of Plant Research.
- Learn new and established techniques and interpretations through diagnostic and testing procedures.
- Understand advance theory of MET techniques including G x E interaction through Factor Analytic models.

Register your interest for a workshop, by contacting the team at: sagiwest@curtin.edu.au

Curtin University GRDC Hosted by the Statistics for the Australian Grains Industry - Western Node (SAGI - WEST)

The SAGI-West workshop flyer



CCDM researcher Jordan Brown presents at a SAGI-West training session for agronomists.



Curtin for Agribusiness Profitability (C4AP)

Julia Easton

C4AP Group Leader
Senior Research Fellow
Email: julia.easton@curtin.edu.au

C4AP is an initiative within CCDM delivering next generation agribusiness and spatial data analytics research to underpin future farm profitability and sustainability.

This multidisciplinary group brings together expertise from farming systems, spatial science, GIS, data science and agribusiness to visualise farm data at within-paddock scale and support data-driven decisions about land use optimisation, risk and return on investment and agricultural production in a water-limited environment. In this initiative, researchers work with technology and industry partners to investigate use cases for research capability and co-innovate to deliver digital tools for WA farmers that drive profitability and sustainability.

As data analytics and machine learning rapidly progress with technology advances, the gap between what is possible and what happens in a farm business is getting larger. C4AP is targeting this gap by bringing high resolution data layers (yield, NDVI, soil, elevation, cost of production, price etc.) into map format with a focus on profitability at the sub-paddock scale both in-season and over time. The initiative aims to understand return on investment for inputs and how this varies spatially, within

a paddock and across the farm enterprise. This group's ability to visualise and analyse farm data (production and gross margin), experiment (design and analyse paddock scale experiments) and predict treatment response within a paddock and across the farm is coupled with a strong track-record in working with farm businesses.

Julia Easton, group leader for C4AP, was awarded the 2023 Curtin University Research & Engagement Award for Research Excellence – Partnership in recognition of outstanding research with a particular focus on making a difference through partnerships.



CCDM researcher and C4AP group leader Julia Easton collecting data for the on-farm water demand project

C4AP Projects

On Farm water demand in the South-West of WA
Digital Edge: next gen agribusiness analytics for the Eastern Wheatbelt

Digital Edge Program

Agri-Analytics Hub

Funding body

Food Agility CRC

The Australian Government's Agricultural Innovation Hubs Program, with support from CCDM, and initiated through the South-West WA Drought Resilience Adoption and Innovation Hub

WA Government's Department of Jobs, Tourism, Innovation and Science – Science Agribusiness Connect Program

Food Agility CRC

On farm water demand: Improving future water-use in horticulture in the South-West

CCDM project team: Julia Easton (project leader), Mark Gibberd, Leidy Luna Cabeza, Simon Koric and Stan Mastrantonis.

Collaborators: WA State Government Department of Jobs, Tourism, Innovation and Science, the Department of Primary Industries and Regional Development, SWAN Systems, WildEye, Southern Forest Food Council.

Key points

- The research team provided 27 horticulture producers with near real-time data for on-farm water use and the relevant tools to manage irrigation in their own business.
- Irrigation data (avocados, apples, truffles, wine grapes and potatoes) collected over four growing seasons has been fused with publicly available, remote-sensed data.
- A key outcome of the project was the development of a machine-learning derived crop classification model to quantify the growing area of each crop in the catchment.

To build resilience in a changing climate, the On-Farm Water Demand (OFWD) project is designed to address the gap in data on water demand in food production in the Warren-Donnelly catchment, near Manjimup in south-west WA. The project has enabled horticulture producers to improve their management of water through data analytics, ensuring more sustainable and profitable food production.



On Farm Water Demand Field Day, delivered as part of the Future Drought Fund Science to Practice forum, Manjimup, featuring CCDM staff Simon Koric (far right) and Mark Gibberd (centre)

Working with multiple industry partners and 27 horticulture producers involved in wine grapes, potatoes, truffles, avocados or apples, the research team provided producers with near real-time data for on-farm water use and the relevant tools to know how water is used in their own business, leading to better management decisions.

Project participants highlighted a key outcome of the project was benchmarking their irrigation practices against other farms. This was evident from the seasonal review discussions, where participants could see how their water use compared to others as well as comparing monthly crop water demand to total water applied (irrigation plus rainfall). In some cases, irrigation was well above the water demand, which could be attributed to a large, unseasonal rainfall event at the end of the month, for example.

The project has been extended to December 2024, which will allow a fourth season of irrigation data collection. The team will finalise the cost of production data collection and aggregation to understand water profitability (\$/ML) for the crops produced in the region. Finally, fusion of the data layers into GIS mapping format will be used to model current crop water demand and water deficit for the study period. The model will help highlight the value of water for food production and industry benefits for the region.

This project is funded by Food Agility CRC.



CCDM researcher Julia Easton with collaborator John Bussell of SWAN Systems at the 2023 Food Agility CRC Digital Agriculture Summit, holding the Food Agility Research Excellence Award for Industry Engagement for the On-Farm Water Demand project

Next generation analytics approach for a resilient Eastern Wheatbelt

CCDM project team: Julia Easton (Project Leader), Mark Gibberd, Arnold Salvacion, Kai Bagley and Finlay Schaper.

Collaborators: Merredin and Districts Farm Improvement Group, WA No-Tillage Farmers Association and three farm businesses from across WA.

Key points

- Through the development of the Yield Research Dashboard (YRD), the research team worked with Eastern Wheatbelt growers to visualise paddock scale statistics and multi-season yield data to help describe within paddock variability in crop performance and profit.
- The YRD has helped farmers to engage with their data as well as encourage conversations about the variability in yield and the potential yield constraints.
- The project team used the tool for co-innovation of research outputs, working with the project participants to ensure analysis and data visualisation are relevant and applicable.

For farmers, profitability of production provides a common basis for decisions, however, working out the 'how and when' to adopt changes to production systems is not so clear. Recent advances in spatial data analytics and the density of available data provides opportunities for advancing agribusiness analytics to support farmers understand risks in decision making.

In this project, the research team worked with three farm businesses from the Eastern Wheatbelt to undertake analyses to identify profitable or unprofitable areas within each paddock and assess the impacts of production systems changes on future productivity. Using on farm data and remotely sensed data, the team carried out co-design engagement sessions with the grower and agronomist to develop a next generation analytics approach.

This involved the development of a Yield Research Dashboard to visualise farm data and analyse crop production and profitability at within-paddock scale. This dashboard allows the visualisation of historical yield (crop production), analyse crop performance (average normalised yield, by crop), stability of yield over time, categorisation of productivity stability (consistently high, consistently low and inconsistent), likelihood of exceeding a break-even yield (based on past crop performance) and long-term profitability (simple gross margin analysis based on production). This has helped to facilitate engagement of farmers with their data as well as encourage conversations about the variability in yield and the potential constraints and strategic placement of inputs.



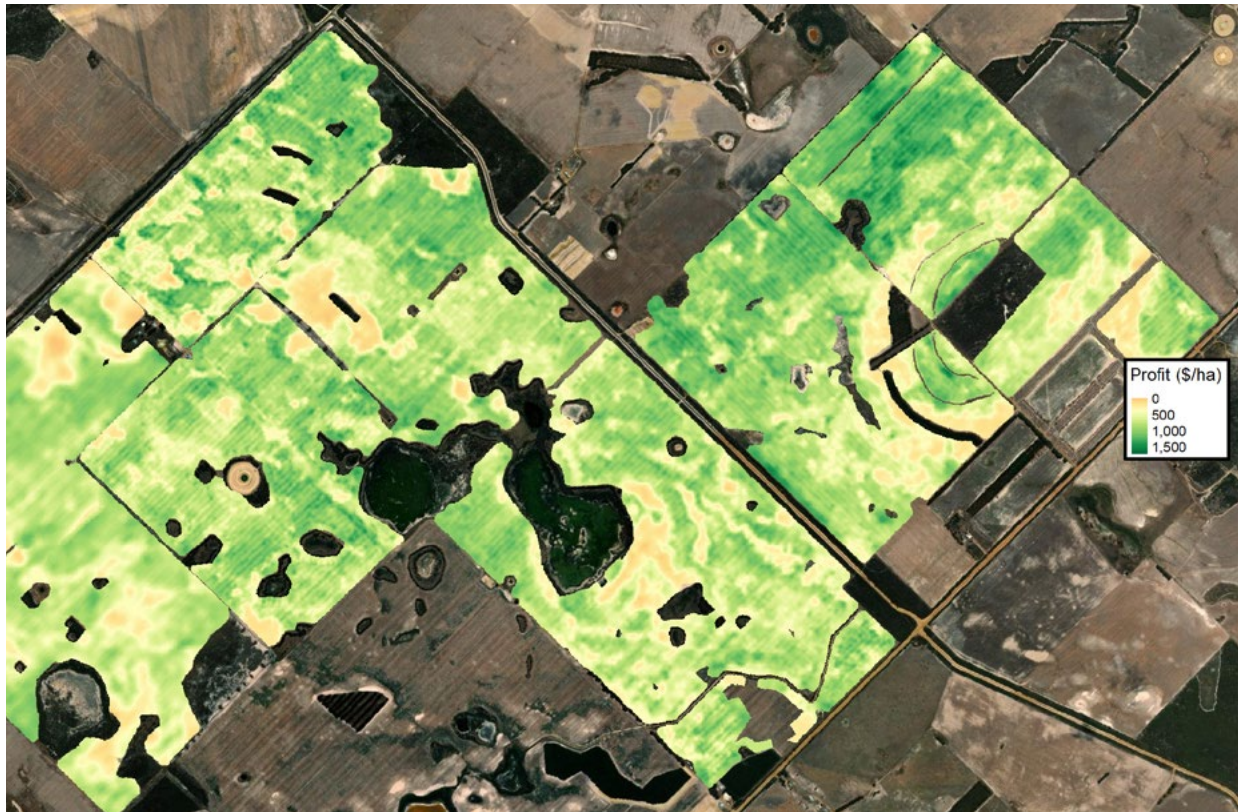
CCDM researcher Finlay Schaper presents a poster on the Yield Research Dashboard at the 2023 Science Symposium for Curtin's School of Molecular and Life Sciences

Concluding in 2023, the intent of this investment was to move the focus of debate from biophysical constraints to robust economic analysis of both the constraint and the potential solution. Thereby placing the farmer into an informed situation which complements their knowledge leading to improved confidence to adopt change.

This project was funded by the Australian Government's Agricultural Innovation Hubs Program and was initiated through the South-West WA Drought Resilience Adoption and Innovation Hub.



By working with growers and their yield data, the research team can help describe within paddock variability in crop performance and profit



Profitability map of a wheatbelt farm



CCDM researchers Julia Easton, Xianbin Cao, Kai Bagley, Jordan Brown, Leidy Luna Cabeza and Arnold Salvacion discuss the Digital Edge project



CCDM researchers Arnold Salvacion, Matthew Nguyen, Finlay Schaper, Xianbin Cao and Leidy Luna Cabeza work together on this project

Digital Edge Program: Giving growers the edge to embrace digital agriculture

CCDM project team: Julia Easton (Project Leader), Mark Gibberd, Arnold Salvacion, Jordan Brown, Mathew Nguyen, Finlay Schaper and Kai Bagley.

Collaborators: WA Government's Department of Primary Industries and Regional Development (DPIRD) and Department of Jobs, Tourism, Science and Innovation (DJTSI), the Grower Group Alliance, Society for Precision Agriculture Australia (SPAA) and six farm businesses from across WA.

Key points

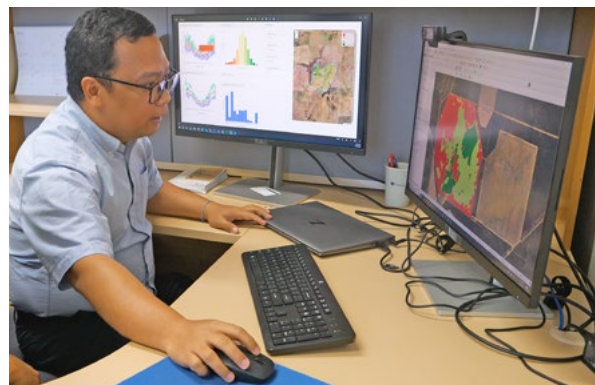
- This project has been successful in building capability in Digital Agriculture, with three CCDM researchers recruited to work on projects in this space.
- The project also worked with a cohort of farmers and industry members to develop critical data cleaning and analytics pipelines for quantifying within-paddock variation, risk and return on investment.
- Data and digital training needs for Australian agriculture were identified through industry masterclasses with farmers, agronomists, technology companies and researchers.

Coming to an end in November 2023, the Digital Edge project was able to successfully build capability in Digital Agriculture across two interconnected activities – improving human resource capability through industry and university training and developing research capability to manage risk and return on investment through

agribusiness data analytics. The first of these was addressed by the recruitment of three CCDM researchers to work on projects relating to Digital Agriculture.

A key aspect of this project was the establishment of a cohort of engaged farmers, agronomists and industry professionals from all four of WA's major grain growing regions. Using at least five years of yield and agribusiness data from cohort members, the team's spatial analysis could provide a granular assessment of yield, areas of high, medium and low production, return on investment for individual and aggregated crops and seasons (Figure 5).

Working with the cohort, the project team developed critical data cleaning and analytics pipelines for quantifying within-paddock variation, risk and return on investment. This led to the development of prototypes for the post-acquisition data analytics pipelines including the development of raster s for statistically driven yield aggregation, cluster analysis for profitability and variable rate technology (VRT) s and paddock-scale experiment design and application for unpacking drivers of yield constraints.



As part of this project's aim to build capability in Digital Agriculture, Arnold Salvacion was recruited to the research team for his expertise in GIS, agronomy and spatial analytics



CCDM researcher Julia Easton with collaborator Bindi Isbister from DPIRD facilitating a masterclass on data interoperability with industry leaders at the SPAA Symposium 2023

Masterclasses marked a major success for this project, with one industry masterclass event (aligned with SPAA conference in Perth) attracting over 50 farmers, agronomists, technology companies and researchers from across Australia. This event was able to identify data and digital training needs for agriculture and draw on the existing experience from the industry and bring together the breadth of representatives required to tackle a system-wide challenge (i.e. data interoperability).

This project is funded by DJTSI as part of the Science Agribusiness Connect program.



CCDM researcher Julia Easton (right) and Pawsey Supercomputing Research Centre CEO Mark Stickells (middle) discuss this project with Science Minister Stephen Dawson MLC

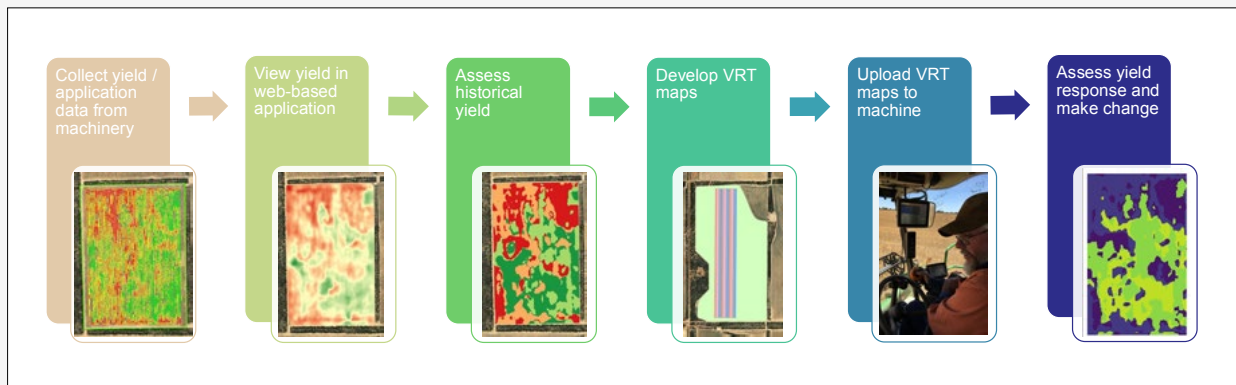


Figure 5. A summary of the steps involved in utilising digital agriculture, developed by the Digital Edge project



Digital Edge project held a co-design workshop in the data visualisation laboratory at the Pawsey Supercomputer with growers and their agronomists, visualising their farm data on a 2.5 x 4m high-definition screen

Agri-Analytics Hub: A new decision support tool to boost agri analytics

CCDM project team: Julia Easton (Project Leader), Mark Gibberd, Arnold Salvacion, Alex Cao, Kai Bagley and Finlay Shapley.

Collaborators: Food Agility CRC, NGIS, Farmanco, WA Government's Department of Primary Industries and Regional Development (DPIRD) and Department of Jobs, Tourism, Science and Innovation (DJTSI).

Key points

- The Agri-Analytics Hub (AAH) will be a decision support tool that will help farmers analyse variability in crop performance and profitability at within-paddock scale.
- Building on research developed in Digital Edge, On Farm Experimentation projects and AAGI, the AAH team are developing robust methods for analysing soil amelioration strip trials using historical trial data provided by DPIRD.
- Data pipelines for within-paddock visualisation and analysis have already been developed with an engaged cohort of farmers and agronomists.

Farmers have access to more data than ever before, which has led to an increase in demand for a scientifically rigorous decision support tool to help them visualise and analyse their farm data. This demand has led to the Agri Analytics Hub, a new collaborative research project with a main aim to help farmers evaluate variability in crop performance and profitability at an in-paddock scale.

The research team have already begun work with a cohort of engaged growers and agronomists, working with them to develop data pipelines to support within-paddock visualisation. By enabling them to visualise and analyse yield and profit within the paddock first, the research team are ensuring a better understanding of paddock performance. Following this, the team will help the engaged cohort of growers and agronomists establish experiments that are statistically robust and can allow scalability of results to the whole farm.



Julia Easton (CCDM), Alice Butler (Farmanco), Matt Stewart (NGIS), Kelly Ryan (Farmanco), Brent Pritchard (Farmanco), Gordon McDonnell (NGIS), Greg Easton (Farmanco) and Mark Gibberd (CCDM) are all part of the Agri-Analytics Hub project team



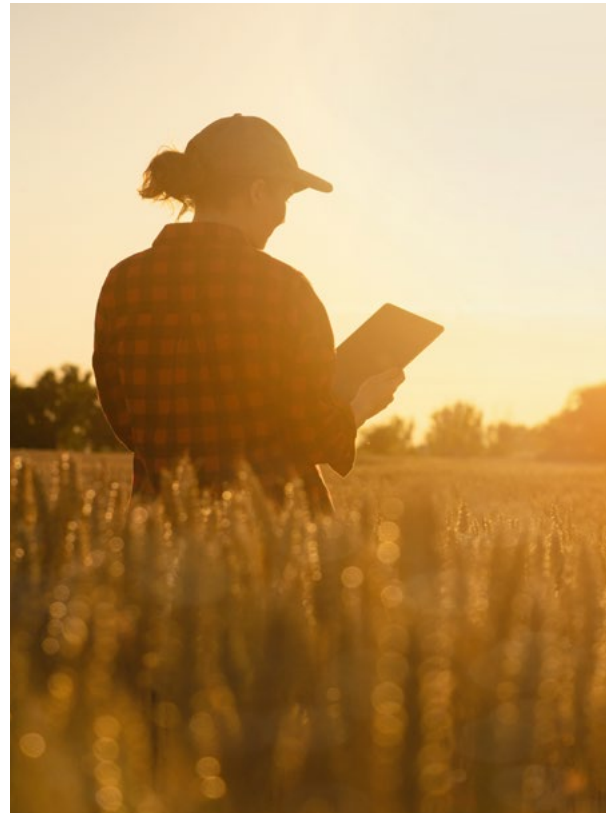
CCDM researcher Julia Easton presents at the Dumbleyung Ag TechXPO on the Agri-Analytics Hub

Research so far has built on next-generation agribusiness research already developed by the Curtin for Agribusiness Profitability Initiative through the Digital Edge and On Farm Experimentation projects. These projects have enabled the recruitment of data scientists, GIS specialist and statisticians to the C4AP team with the opportunity to co-design decision support tools with farmers and agronomists using results obtained from their own production system.

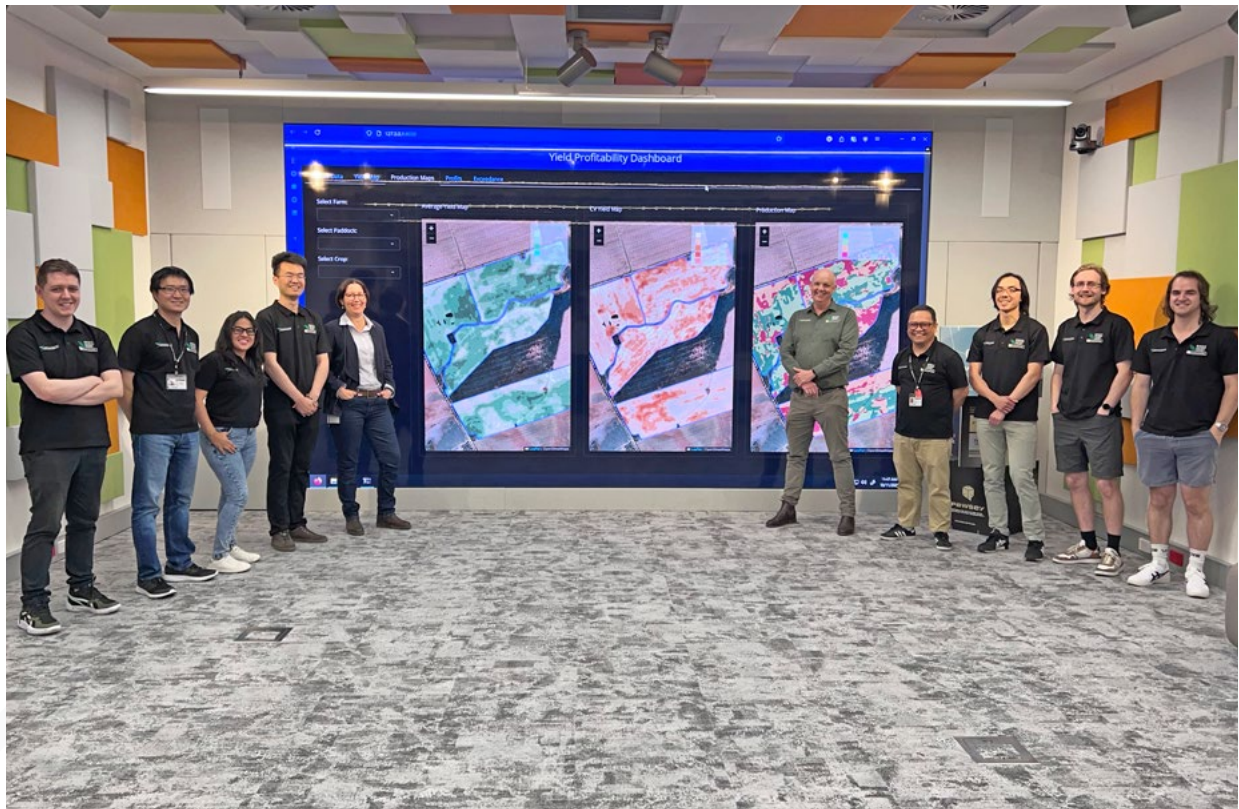
This project is funded through the Food Agility CRC.



CCDM researcher Julia Easton and director Mark Gibberd in the field



Farmers will be able to use the Agri Analytics Hub to support decision making



The CCDM Curtin 4 Agribusiness Profitability team at the visualisation laboratory at the Pawsey Supercomputer (left to right: Finlay Schaper, Zhanglong Cao (AAGI), Leidy Luna Cabeza, Xianbin Cao, Julia Easton, Mark Gibberd, Arnold Salvacion, Matthew Nguyen, Jordan Brown and Kai Bagley)

CCDM Engagement

Southern WA Barley Disease Forum, Albany

Key points

- 60 industry members joined in the discussion on how to better manage net form and spot form net blotch for future epidemics.
- A whole of farming system approach is needed – combining knowledge on host resistance, pathogen population, fungicide resistance and optimisation of fungicide strategy.
- This forum has helped to tease out strategies needed for reducing barley diseases, ensuring that barley continues to be a profitable crop for the region.

In July, CCDM and Stirlings to Coast Farmers coordinated a GRDC forum that brought together more than 60 industry members with an interest in barley disease management and fungicide resistance. The event was successful in achieving the two aims:

- To explore a three-way interaction between new variety resistance, pathogen dynamics as well as the management impacts of disease control to pull together a whole farming system approach to managing disease.
- To facilitate a discussion between researchers, breeding companies and chemical companies as well as local growers and advisors, to explore future opportunities for managing barley disease.

CCDM has a strong history of working with growers from Southern Western Australia within the Barley Disease Cohort Project, which created a lot of new understanding about both spot form and net form of net blotch and fungicide resistance in this region over the past 4 years.

At the workshop, CCDM Director Professor Mark Gibberd said knowledge of fungicide resistance and the biology of the net blotch pathogens has increased remarkably in recent times.

“They are two of the most complex pathosystems that we work with. There are multiple mutations conferring fungicide resistance and pathogen populations have proven to be highly dynamic from year-to-year, paddock-to-paddock and even within the paddock,” Professor Gibberd said.

“But the fact of the matter is, even with growing disease pressure, last season was a bit of a wake-up call. It has become clear that a whole of farming system approach is needed – in particular, we need combine our knowledge of host resistance, pathogen population, fungicide resistance and optimisation of fungicide strategy for the best chance of cost-effective control.

“This forum has helped to tease out strategies needed to develop and deploy tools used for reducing barley diseases, ensuring that barley continues to be a profitable crop for the region.”

The event was highly rated in the evaluation, with many people finding the workshop session at the end the most useful.



Mark Gibberd presenting at the Southern WA Barley Disease Forum in Albany



Agronomists, researchers and industry members discuss disease management at the Forum

Crop Protection Forum, Adelaide

Key points

- Every year CCDM partners with AHRI and Cesar Australia to showcase the latest research in chemical resistance to industry members.
- In 2023, the event was in Adelaide, with a record 140 registrations, with the event being livestreamed for the first time.
- Panel sessions involving local agronomists at the beginning and end of the event have ensured research is on target for what's needed in the region.

Every year CCDM partners with the Australian Herbicide Resistance Initiative (AHRI) and Cesar Australia to showcase the Crop Protection Forum, a national event that engages industry in the latest research in herbicide, insecticide and fungicide resistance.

The 2023 Crop Protection Forum was held in Adelaide, with an agenda filled with informative presentations throughout the day. More than 140 registered growers and agronomists joined in the discussion to hear about how to make on-farm changes to improve the ongoing challenges of managing resistance.

The record number of registrations was attributed to the event being livestreamed for the first time, ensuring anyone, in any region, can be part of the event.

CCDM's Fran Lopez-Ruiz, Johannes Debler and Mark Gibberd were all in attendance presenting fungicide resistance status updates in grain crops, possibilities



CCDM Director Mark Gibberd presenting at the Crop Protection Forum in Adelaide

for ascochyta blight in-field tests and new fungicide resistance mapping tools.

GRDC Crop Protection Manager – South, Ruth Peek, said the forum offered agronomists and advisers the latest information on research in resistance development in pest weeds and disease, and opportunities to discuss optimal management strategies with expert researchers from across Australia.

“Knowing how best to respond and manage resistance isn’t always straightforward. And with resistance on the rise, this forum also gives the industry a chance to discuss future directions, with conversations on new and emerging problems, diagnostic advances and the role of chemical control options,” Ms Peek said.

Other topics on the agenda included: Resistance status updates, novel approaches to predicting and monitoring insecticide resistance, and future use of pesticides.



CCDM researcher Johannes Debler discusses his lentil research with other attendees



CCDM researcher Fran Lopez-Ruiz presenting on fungicide resistance

GRDC Grains Research Updates, Perth

The 2023 Grains Research Updates in February held an exciting buzz amongst attendees. At this year's updates, CCDM was able to engage with more than 600 people at Crown Towers in Perth on the latest research outcomes coming from the centre.

Two CCDM presentations featured in the agenda. CCDM researcher Kar-Chun Tan presented his research on understanding effector regulation on the path to improving genetic resistance in wheat to septoria nodorum blotch. CCDM researcher Fran Lopez-Ruiz presented an update on fungicide resistance status in Western Australia, as well as sharing how the Australian Fungicide Resistance Extension Network (AFREN) is helping the industry better manage the challenges of fungicide resistance.

A CCDM information booth allowed CCDM to appear as an industry leader amongst other booth occupants representing many grains industry organisations. The stall promoted CCDM research and helped researchers to network with other grains industry members.



The CCDM information booth at the 2023 GRDC Grains Research Updates in Perth

Mingenew, Dowerin and Newdegate Field Days, August-September

Ever since CCDM's establishment in 2014, it has been a tradition to hold a display within the GRDC marquee at the Mingene, Dowerin and Newdegate Field Days, with 2023 being no different. The field day events are a golden opportunity for CCDM staff to lay the "pipettes" down and be part of an industry event, to share what they do at CCDM and listen to the issues faced by industry. In 2023, 14 staff took part in the CCDM display.

At Mingene Expo, CCDM researchers were able to speak to different groups about their new technology and how it could in future be translated over to a disease space. At Dowerin Field Days CCDM researchers were able to discuss how resistance for certain diseases had improved and changed with the different crop varieties. At Newdegate Field Days staff members were giving some good management advice to growers about fungicide resistance.

CCDM communications officer Lisa Smith coordinated CCDM's presence at all three field days, and said it was a great opportunity to see how CCDM research makes a difference to industry members.

"From farmers to community members and school kids, it was great to be able to talk to people of the region and get a feel for what they are going through with their farming businesses," she said.

"The primary school kids loved taking part in a mini DNA experiment too and it was great to show them that DNA is a large part of our work here at CCDM."



CCDM researchers Linda Thomson and Kul Adhikari at the Newdegate Field Days in 2023

GRDC Board visit CCDM, with GPA and GGL, Bentley Campus

The GRDC Board of Directors and Executives plus participants from Grain Growers Limited and Grain Producers Australia visited CCDM in September as an opportunity to value add to their board meetings in Perth. The large group toured the CCDM facilities and were able to participate in interactive activities relating to CCDM research. The group seemed to really enjoy this, asking questions and getting involved. Many photos were taken and posted on various social media accounts, with this visit representing the most shared and talked about event on the CCDM calendar in 2023.



CCDM researcher Simon Ellwood discussing his research during the GRDC, GPA and GGL Board visit



CCDM researcher Pao Theen See discussing her work during the visit

Student events, including Curtin Open Day, Discover! and Chemistry Night

CCDM coordinated a stand at Open Day and were able to connect with many future students considering agriculture/agribusiness as a degree. The team also coordinated a stand at Discover! – a Curtin Outreach event that attracts highschool students to engage with various Curtin research centres to spark interest in STEM areas. Events such as these can help attract postgraduate students to study with CCDM.



CCDM communications officer Lisa Smith at Discover! An event for high school students to get excited about studying at Curtin

Nanopore Sequencing for Biosecurity Workshop, Bentley Campus

Nanopore sequencing has revolutionised sequencing for biosecurity due to its portability, small footprint, and minimal capital investment. To fully exploit the potential of Nanopore sequencing and to modernise Australian biosecurity, a workshop was coordinated by CCDM to build capacity and proficiency in sequencing and data analysis.

This two-day workshop event attracted more than 50 external researchers to Curtin's Bentley Campus to investigate Nanopore long-read sequencing applications and its use in agriculture and food security, such as crop pathogen and agrochemical resistance detection. It was successful at sharing collective knowledge on this research technology with fellow colleagues, so that Nanopore sequencing can be used to generate important, high impact outcomes for biosecurity research.



Researchers at the Nanopore Workshop at Curtin



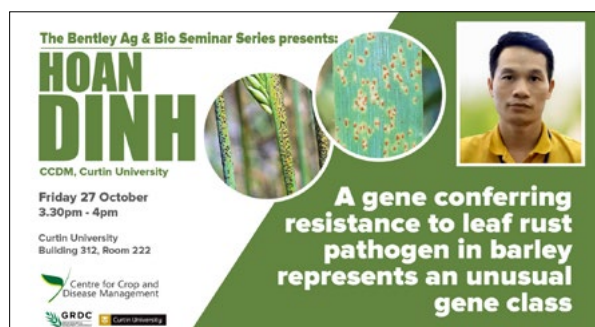
CCDM researchers Fatima Naim, Katherine Zulak and Johannes Debler using nanopore sequencing technology to carry out research in crop diseases

CCDM Seminars, Bentley Campus

Each week CCDM hosts a seminar at Curtin's Bentley Campus that are open for anyone to attend. The seminar series feature presenters from Curtin University, the University of Western Australia, Murdoch University, the Department of Primary Industries and Regional Development, CSIRO and many other research organisations in Perth. International visitors are also regularly showcased in a CCDM seminar, with every seminar followed by networking with CCDM researchers. The seminars have proven to be a big success for the science community and industry members interested in the latest agriculture and biology research.



Attendees at the CCDM Seminar where researcher Elaine Davidson presented on dieback-free gravel for road construction



An example of a CCDM Seminar social media post



CCDM Director Mark Gibberd presents on the new AAGI initiative at a CCDM Seminar

CCDM research outputs presented through media releases, blog, newsletters, podcasts and videos

The Spotlight is CCDM's main communication channel to our target audience – the agronomist and grower. Anyone can sign up to the Blog from the CCDM website, to receive the latest discoveries that “can be used” by the grains industry. Every story has a call to action at the end, to put the research into practice.

CCDM News and Updates is CCDM's newest newsletter, launched in 2023. The main aim of the newsletter is to update readers on CCDM's activities and movements. CCDM media releases are also posted here to share significant announcements. Anyone can sign up to the newsletter on the CCDM website.

The Crop Disease Podcast is a podcast presenting the latest crop disease information that is of interest at the time of releasing. It ties in CCDM research and always includes a CCDM co-host. It always includes a guest from the Australian grains industry, typically an agronomist or a pathologist. To listen, search Crop Disease Podcast in Spotify, Apple Podcasts, or on any other podcast provider.

CCDM's YouTube has increased the number of videos uploaded in the past year. CCDM uses video to explain new science discoveries to industry members and for social media engagement.

CCDM uses X and LinkedIn to share information from researchers and new discoveries. For instance, every CCDM scientist who attended a national or international scientific conference and delivered a presentation or presented a poster, was promoted through CCDM social media. Follow CCDM on X: @theCCDM and LinkedIn: Centre for Crop and Disease Management.



CCDM's blog that includes information that is useful to agronomists



CCDM's podcast that integrates CCDM research with industry challenges

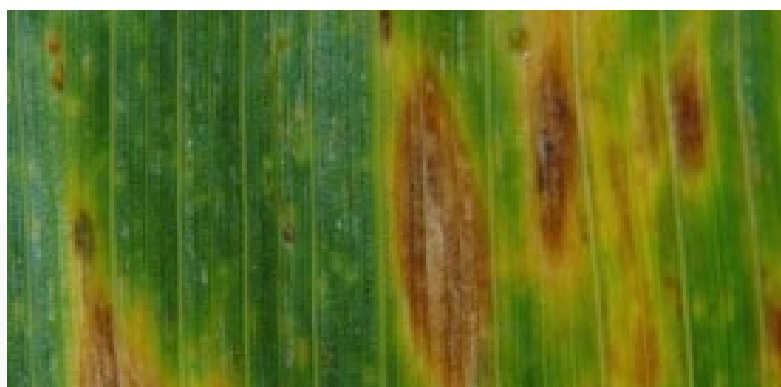


CCDM's newsletter that includes all news and updates coming from the centre, all in one place

CCDM Postgraduate Students of 2023

Name	Topic	Supervisor/s
Jordan Campbell	In planta dynamics of flutriafol and prothioconazole	Jordi Muria Gonzalez, Hendra Gunosewoyo
Stacey Carter	Value of e-Portfolios in Agribusiness educational programs to optimise employability and improve transition from student to employee	Sarita Bennett, Jacob Hawkins
Johannes Debler	Effector discovery in ascochyta pathogens of lentil and chickpea	Bernadette Henares, Lars Kamphuis, Robert Lee, Karam Singh
Patrick Duong	Optimising digital customer journey and leveraging digital marketing strategies to attract customer's attention, desire and purchasing intention to Australian agrifoods	Billy Sung (School of Marketing), Sean Lee, Julia Easton
Carolyn Graham-Taylor	Pan-genomic analysis of <i>Sclerotinia sclerotiorum</i> small RNAs and investigations into their mode of delivery to plants	Mark Derbyshire, Lars Kamphuis, Toby Newman
Naomi Gray	Australia-wide pan-genome sequencing of hundreds of fungal isolates and multiple crop pathogen species to study virulence gene evolution	James Hane, Pao Theen See
Viet-Cuong Han	Impact of soil microbiological health on persistence of <i>Sclerotinia sclerotiorum</i> in agricultural ecosystems	Sarita Bennett, Bec Swift, Pippa Michael
Kealan Hassett	Population Structure and Virulence of Barley Spot Form of Net Blotch Isolates in Western Australia	Simon Ellwood, Jordi Muria Gonzalez
Thomas Hill	Validating candidate genes for a dsRNA-based method of crop protection against the fungal pathogen <i>Sclerotinia sclerotiorum</i>	Lars Kamphuis, Mark Fisher, Mark Derbyshire
Leon Hodgson	Landscape Gene Flow of Demethylase Inhibitor Resistance in <i>Pyrenophora Teres F. Teres</i>	Ayalsew Zerihun, Fran Lopez Ruiz, Mark Gibberd
Md Mohitul Hossain	Comparative bioinformatics across crop pathogen pan-genomes and developing novel solutions for effector-based crop disease management	James Hane, Huyen Phan
Robabeh Hosseini	Characterisation of disease tolerance in cereal crops	Fatima Naim, Mark Gibberd, Ayalsew Zerihun
Karina Khambatta	Imaging techniques to assess plant health	Mark Hackett (MLS Chemistry), Fatima Naim
Sundara Link	Mutational approaches to dissecting the spot form net blotch - barley pathosystem	Simon Ellwood, Pao Theen See
Michael McDonald	Resilience as a determinant of the viability of agrifood production	Mark Gibberd, Julia Easton, Jacob Hawkins, Zhanglong Cao
Varthini Govindaraju Punithan	Modelling the effect of barley traits on the in-planta dynamics of fluxapyroxad and its effect on protection.	Jordi Muria Gonzalez, Mark Gibberd

Name	Topic	Supervisor/s
Anjana Sharma	Evaluation of histone acetyltransferases in <i>Parastagonospora nodorum</i> as potential fungal targets for alternative disease management in cereal crops	Fran Lopez-Ruiz, Kar-Chun Tan, Chala Turo, Liz Czislawski
Shota Morikawa	Elucidating the mechanism of necrotrophic effector regulation in a fungal pathogen of wheat	Kar-Chun Tan, Bernadette Heanares, Evan John, Carl Mousley
Arundhati Singh	Movement and longevity of fungicides fluxapyroxad and mefentrifluconazole	Jordi Muria Gonzalez, Hendra Gunosewoyo, Mark Gibberd, Liz Czislawski
Emma Thackway	Novel sources of resistance to combat <i>Ascochyta lentis</i> in the agriculturally important Australian pulse crop lentil (<i>Lens culinaris</i>)	Lars Kamphuis, Bernadette Heanares, Robert Lee
Linda Thomson	Farm management drivers of fungicide resistance frequencies in <i>Pyrenophora</i> spp. across a spatially variable environment	Mark Gibberd, Sarita Bennett
Ancy Kuthokathan Tony	Developing genetic resistance in wheat to powdery mildew	Kar-Chun Tan, Huyen Phan, Simon Elwood, Daniel Mullans
Asiri Padukka Vidanalage	Identification and characterization of novel <i>Septoria nodorum</i> blotch resistant genes/ QTLs in wheat (<i>Triticum aestivum</i> L.)	Huyen Phan, Mark Gibberd
Janardhan Vignarajan	Correction of remotely sensed images through calibration to improve limits of feature change detection for high throughput, quantitative crop sensing and phenotyping applications	Ayalsew Zerihun, David Belton, Peter Fearn (Curtin Medical School)
Naomi White	Small RNAs: the battle ground between plants and their pathogens	Mark Derbyshire, Lars Kamphuis, Toby Newman
Meg Willians	Developing X-ray tools to image metal speciation in plants	Mark Hackett (MLS Chemistry), Fatima Naim



CCDM Staff in 2023

Kul Adhikari – Research Assistant

Kai Bagley – Data Scientist

Maïke Bollen – Research Officer

Jordan Brown – Data Scientist

Xianbin Cao – Research Fellow

Zhanglong Cao – Research Fellow

Steven Chang – Research Assistant

Kefei Chen – Research Fellow

Bethany Clark – Research Assistant

Kasia Clarke – Senior Research Officer

Yutathkarn Coles – Casual, Research Assistant

Rachael Crockett – Research Assistant

Sabrina Cuellar – Research Assistant

Catherine Cupitt – Research Assistant

Elizabeth Czislawski – Research Fellow

Jade Davis – Casual, Research Assistant

Johannes Debler – Research Assistant

Mark Derbyshire – Research Fellow

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Kejal Dodhia – Research Assistant

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CCDM Publications

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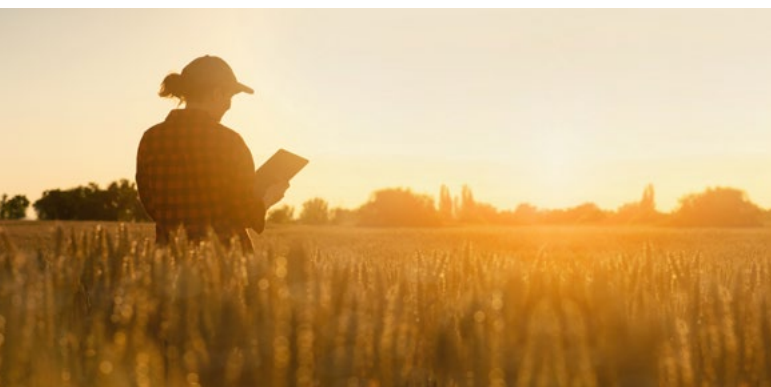
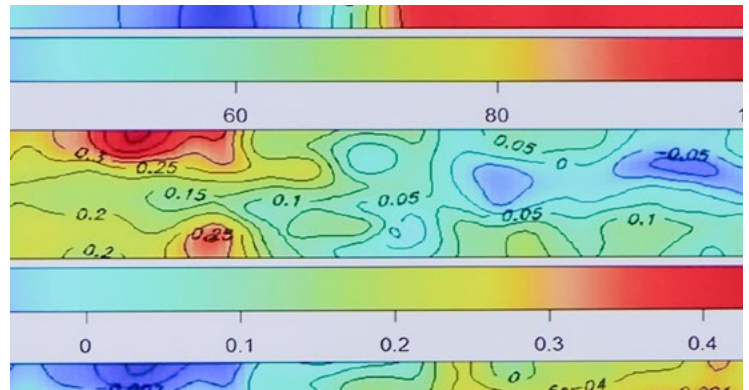


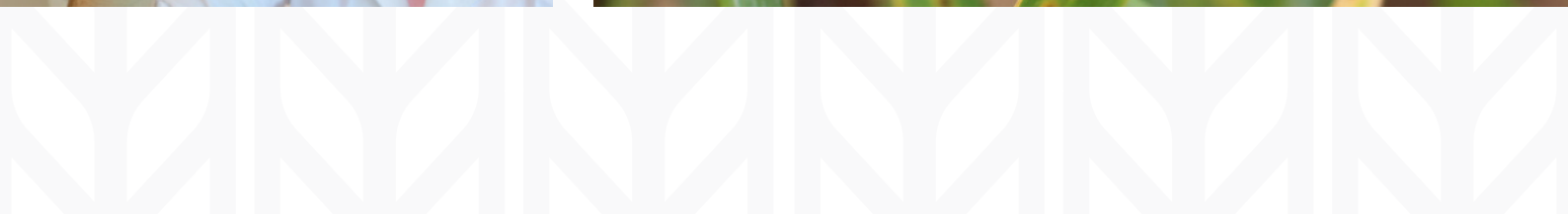
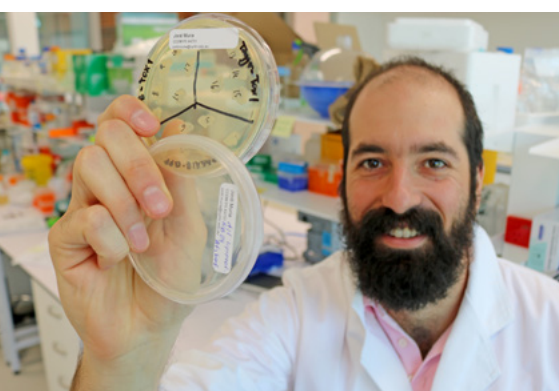
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