Centre for Crop and Disease Management

GRDC Grains Research & Development Corporation | Curtin University

2015

ANNUAL REPORT

CENTRE FOR CROP AND DISEASE MANAGEMENT

The CCDM Team

BACKGROUND

The Centre for Crop and Disease Management was launched in 2014 and is co-funded by GRDC and Curtin University, investing $100 million over a five-year period.

Its major aim is to improve the economics and sustainability of farming by tackling major crop diseases using molecular genetics and fungicide research, while contributing towards improved agronomy and farm management practices.

Since its launch, the CCDM has continued to build on Curtin's previous work with the Australian Centre for Necrotrophic Fungal Pathogens (ACNFP), whose discoveries and outcomes are saving the industry more than $100 million per year. By 2020, growers' savings from this research are expected to increase to nearly $400 million per year through new varieties and practices, in addition to savings from the decreased use of fungicides.

CCDM's effector work has continued to supply Australian wheat breeders with unlimited doses of purified ToxA, Tox1 and Tox3 for germplasm screening to find septoria nodorum blotch (SNB) and yellow spot resistant varieties. We are working to find other necrotrophic effectors to provide to breeders, as CCDM researchers work on the model that a grain line insensitive to all relevant effectors will be extremely resistant to a given disease. Our effector work has been extended into barley and pulse diseases.

Further to the lab-based genetics and fungicide research, the CCDM works hand-in-hand with breeders, growers and the wider industry, to develop economical integrated disease management (IDM) strategies to all fungal diseases affecting different crops within different farming systems. Projects that look at stubble management, green bridges, the gross margin benefits of rotations and fungicide timing are underway in 2016 and are showing promising results.

CCDM STRUCTURE

The CCDM is divided into 10 research programs, but for simplicity of this report, these programs have been divided into three themes:

- Fungicide Resistance
- Molecular Genetics & Bioinformatics
- Farming Systems, Agronomy & Engagement

2015 PEER-REVIEWED PUBLICATIONS:

- Cockram, J., A. Scuderi, T. Barber, E. Furuki, K. Gardner, N. Gosman, R. Kowalczyk, H. Phan, G. Rose, K. Tan et al. 2015."Fine-mapping the wheat Snn1 locus conferring sensitivity to the Parastagonospora nodorum necrotrophic effector SnTox1 using an eight founder multiparent advanced generation inter-cross population."G3: Genes, Genomes, Genetics 5 (11): 2257-2266.
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- Tan, K. C., Phan, H. T. T., Rybak, K., John, E., Chooi, Y. H., Solomon, P. S. and Oliver, R. P. (2015). "Functional redundancy of necrotrophic effectors – consequences for exploitation for breeding". Frontiers Plant Sci.
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- Tucker, M. A., C. S. Moffat, S. R. Ellwood, K. Tan, K. Jayasena, and R. P. Oliver. 2015. "Development of genetic SSR markers in Blumeria graminis f. sp. hordei and application to isolates from Australia." Plant Pathology 64: 337-343.
- Vela-Corcía, D., D. Bellón-Góme, F. Lopez-ruiz, J. A. Tores, and A. Perez-Garcia. 2014. "The podosphaera fusca tub2 gene, a molecular "swiss army knife" with multiple applications inpowdery mildew research." Fungal Biology 118 (2): 228-241.
- Foley, R. C., J. C. Jimenez-Lopez, L. G. Kamphuis, J. K. Hane, S. Melser, and K. B. Singh. 2015. "Analysis of conglutin seed storage proteins across lupin species using transcriptomic, protein and comparative genomic approaches." BMC Plant Biology 15: 106-106.
- Thatcher, L. F., L. G. Kamphuis, J. K. Hane, L. Onate-Sanchez, and K. B. Singh. 2015. "The Arabidopsis KH-Domain RNA -Binding Protein ESR1 Functions in Components of Jasmonate Signalling, Unlinking Growth Restraint and Resistance to Stress." PLoS ONEn/a-n/a
- Kamphuis, L. G., J. K. Hane, M. N. Nelson, L. Gao, C. Atkins, and K. B. Singh. 2015. "Transcriptomic sequencing of different narrow-leafed lupin tissue types provides a comprehensive uni-gene assembly and extensive gene-based molecular markers." Plant Biotechnology Journal 13 (1): 14-25.
- van den Bosch, F., N. Paveley, B. Fraaije, F. van den Berg, and R. P. Oliver. 2015. "Evidence based resistance management." In Fungicide Resistance in Plant Pathogens Principles and a Guide to Practical Management, 63-76. Japan: Springer.
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DIRECTOR'S REPORT
MARK GIBBERD
CCDM DIRECTOR

Though relatively new, our centre has been able to deliver some major outcomes and strengthen relationships with industry with respect to our expertise in foliar fungal pathogens. We also continue to grow our capacity to examine wider crop management issues including agronomy, economics, farmer practice and extension.

The co-funded bilateral arrangement between GRDC and Curtin University provides us with the opportunity to be flexible and respond to crop and disease management challenges in a timely manner. It also allows us to tackle fungal diseases using a multi-faceted approach, by:

1. Focusing on agronomic practice and working hand-in-hand with growers to help improve integrated disease management strategies.
2. Studying fungal pathogens down to the molecular level, and we're generating genetic tools that allow breeding companies to develop disease resistant varieties.
3. Keeping track of new cases of fungicide resistance and spreading messages to growers on how to avoid it, to ensure the few current active compounds remain functional to control disease outbreaks.
4. Using bioinformatics to explore large genome data sets to help find disease-causing genes.
5. Creating the environment through which key learnings are passed to agronomists, breeders, consultants and farmers.

Powdery mildew on barley

Mark Gibberd in front of the new agricultural facility, due to open in the second half of 2016

In 2015 we delivered outcomes that had a direct or indirect benefit to the Australian grain grower, these are presented in more detail in this report. From my perspective, there were three stand-out achievements that were particularly valuable for industry.

The first was the discovery of a promising new durable powdery mildew resistance gene from an Ethiopian barley line. Unlike other durable resistance genes bred in barley, this gene does not reduce yield. This genetic material will be passed onto breeders to breed powdery mildew resistant barley.

The second was the development of two molecular tests that can rapidly detect known mutations associated with fungicide resistance in the field, much faster than current technology. With these methods for fast detection of fungicide resistance, we're helping growers to act early to prevent further mutations from occurring.

The third was the record numbers of students participating in citizen science project, Mildew Mania, which links both primary and high school students with CCDM research to help keep track of pathogen shifts and ensure disease resistant varieties remain resistant. Connecting students to agriculture is crucial in helping to contribute towards a skilled workforce that meets the needs of the grains industry.

Our achievements across 2015 are just the beginning of what our centre has the potential to accomplish, and I look forward to seeing more discoveries revealed and make real differences to grain growers. We know the diseases affecting Australian crops will continue to mutate and present new challenges, but with our capability to stay abreast and in some instances in front of those challenges, we can ensure the technology and innovation coming from our centre is helping farmers become more profitable and sustainable.

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CCDM Director

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THEME 1
FUNGICIDE RESISTANCE

Objective

To develop the necessary tools that will allow growers to prevent, mitigate and minimise the occurrence and impact of fungicide resistance in their crops by:

- Establishing an early warning monitoring system
- Developing new molecular tools for the fast analysis of field samples
- Testing new chemistry in both field trials and laboratory tests
- Unraveling the mechanisms by which pathogens become resistant to fungicides.

Fruiting bodies on wheat stubble

Some key achievements

- The national fungicide resistance monitoring system (also known as 'baiting trials') combined with a national network of trials for the analysis of unregistered antifungal active compounds, have continued to enable researchers of CCDM's Fungicide Resistance Group to be better aware of fungicide resistance, and test new chemicals with different modes of action, ultimately enabling the longevity and widening the currently limited set of fungicides available to growers.
- Molecular tests for fast analysis and detection of fungicide resistance in the field have been developed. LAMP and Digital PCR are two technologies that can rapidly determine the presence of known mutations associated with fungicide resistance (read more in case study below).
- With the help of a network of collaborators, a new sample collection system has been established to better allow industry members to send in samples from across Australia. This system has been useful for the identification of some resistance issues found during the last season.

Wesley Mair and Fran Lopez-Ruiz of the Fungicide Resistance Group

In the pipeline for 2016

The Fungicide Resistance Group will:

- Continue to identify and source new actives that have potential to be included in rotations as part of integrated disease management (IDM) and anti-resistance strategies.
- Continue to investigate the molecular mechanisms controlling resistance found in their samples to date, allowing them to improve detection methodologies and anti-resistance strategies.

CASE STUDY: FUNGICIDE RESISTANCE DETECTION

One of the main concerns for the grains industry is the current turnaround time between sample collection and fungicide resistance analysis.

To solve this problem, the CCDM's Fungicide Resistance Group have worked on developing faster and more accurate methods for detection, allowing the grain industry to adjust the anti-resistance strategies used during the season to respond to specific resistance threats. Digital PCR and LAMP are two such technologies.

Digital PCR

Digital PCR is a technique being used to analyse large amounts of disease DNA to detect and quantify mutations associated with fungicide resistance.

Digital PCR

Digital PCR is a time efficient process with results available within one to two days (previous methods took up to two weeks). Digital PCR is also sensitive and is likened to 'running a fine tooth comb' through multiple samples at once, picking up DNA mutations that may have been missed with previously used laboratory methods.

LAMP

Loop mediated isothermal amplification (LAMP) is a method that is being used to detect the presence of fungal pathogens in the field, even before symptoms are visible on a number of different crop types. LAMP can also be used to detect fungicide resistance.

LAMP has been confirmed as a sensitive and specific method, producing results within 40 minutes, when other methods take up to two weeks.

LAMP

THEME 2
MOLECULAR GENETICS & BIOINFORMATICS

Objectives

To provide plant breeders with the genetic tools needed to breed varieties that have a high level of disease resistance to common crop diseases including:

- Septoria nodorum blotch of wheat
- Yellow spot of wheat
- Net blotch of barley
- Powdery mildew of barley
- Sclerotinia stem rot of canola
- Ascochyta blight of pulses

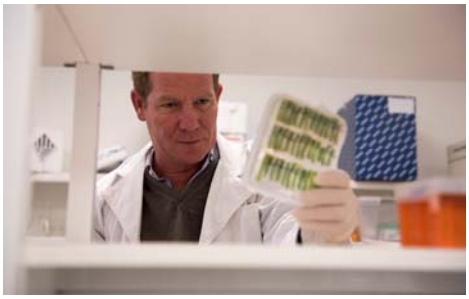
To use bioinformatics to analyse genomes of fungal pathogens for insight into host-pathogen interactions and how they evolve and adapt, and identify novel methods for computationally predicting genes that cause crop disease.

Some key achievements

- Three 'effector' genes have been successfully deleted from *Parastagononospora nodorum*, the pathogen responsible for causing septoria nodorum blotch. The research team was able to show that the fungus *P.nodorum* still damaged leaf tissue, even after the three effectors were removed, showing there are other effectors yet to be found.
- Gene-specific and closely-linked reliable QTL markers have been developed and passed on to breeders. These markers help breeders locate wheat genes that confer sensitivity to known effectors of yellow spot and SNB diseases; including ToxA, Tox1 and Tox3.
- The Stop the Spot campaign continued for its second year in 2015, with 145 samples received from all Australian grain growing regions.
- Candidate effector genes causing net-form net blotch on barely have been identified using its fungal genome sequence. Their proteins are now being isolated and infiltrated onto barley leaves, to pinpoint effector genes which can then be used in breeding programs.
- A published literature review has described current methods for controlling sclerotinia, looking into the feasibility of a conventional breeding route or a genetic modification route to best improve disease resistance in canola to sclerotinia stem rot.
- DNA markers and genome sequencing have been used to provide a picture of the genes expressed during infection of ascochyta blight on pulses. Eventually such novel plant breeding tools will be provided to breeding companies.
- The barley powdery mildew resistance gene – MISt – was confirmed 'defeated' after receiving an early report of powdery mildew in the variety Oxford south of the Stirling Range.
- A promising new durable resistance gene from an Ethiopian landrace, named Eth295, has been discovered and passed onto breeders to breed powdery mildew resistant barley (read more in case study below).
- Distinctive evolutionary patterns of fungal genomes have been observed by using bioinformatics technology, which has helped to predict host-specific and/or laterally transferred pathogenicity genes, potentially pointing to mutation hotspots.
- The *P.nodorum* genome has been annotated again, allowing researchers to more accurately find effector genes causing SNB.

In the pipeline for 2016

- CCDM researchers will compare the susceptibility of hybrid and open pollinator canola varieties to sclerotinia stem rot in a controlled environment and in the field.
- Effector candidates will continue to be screened to narrow down new effectors within pathogens causing yellow spot, SNB and net form net blotch of barley that can be provided to breeders.



Simon Ellwood examining powdery mildew on barley

CASE STUDY: USING ETHIOPIAN GENETICS TO FIGHT POWDERY MILDEW

CCDM's powdery mildew team are 'thinking outside the box' and looking outside Australia for a solution to managing powdery mildew on barley.

For some time, they have been screening exotic barley lines from other countries, trying to find genes with durable resistance that could be introduced to Australian barley lines, and have been successful finding a promising gene within an Ethiopian barley line.

Currently, the best genetic resistance to powdery mildew in barley is reliant on the *mlo-11* allele, which has been widely deployed in Europe and the USA for more than 40 years and provides resistance to all known pathotypes of mildew.

However, while successful at preventing powdery mildew, *mlo-11* has been shown to reduce yields, and therefore an alternative genetic solution is warranted.

The team found a promising new resistance gene that is a variant of mlo-11. This variant is structurally different and does not possess known deleterious effects of all mlo alleles and, therefore, does not affect yield.

Germplasm is now being presented to breeding companies, and will be bred into Australian barley lines. Barley growers can expect this new resistance gene to be available in barley cultivars within the next five years.

Ethiopian line

Baudin, a common barley variety

THEME 3
FARMING SYSTEMS, AGRONOMY & ENGAGEMENT

Objectives

- To minimise the impact of fungal pathogens through economical and adoptable IDM strategies and practices for managing evolution of resistance to fungicides.
- To ensure the adoptable outcomes from research activities undertaken to improve disease management are communicated and extended to growers and other stakeholders.

Some key achievements

- The preliminary results of a field trial repeated in three different locations in the WA wheatbelt have indicated fungicide timing for short season wheat varieties had an effect on yield. The trial aims to discover optimal fungicide timing and frequency for long and short season varieties across different environments.
- A completed pilot study has allowed for a broader project to begin in 2016 to investigate green bridges, looking at fungal populations on common agricultural weed species.
- A new economic model has demonstrated the gross margin impacts of break crop rotations, integrated disease management (IDM) control strategies, and various fungicide application strategies. The model can test a range of scenarios based on choices a farmer might make in managing their crop in the presence of various disease loadings.
- The inaugural AHRI and CCDM Forum brought together more than 100 agronomists, consultants and researchers to discuss the latest research in crop protection.
- 10 media releases, 8 Spotlight articles, 15 brochures/posters, 24 industry presentations and more than 200 tweets (from @theCCDM and @FRGcurtin) were issued to direct important messages to growers and advisers.
- Mildew Mania, a citizen science project which links in with primary and high school students with CCDM research, reached record registrations for 2015 (read more in the case study below).
- An Engagement Reference Committee including CCDM staff, education providers and industry members was formed to discuss ways to increase the number of students choosing agriculture as a career.
- CCDM research was showcased across various Australian field days, forums and expos including Dowerin, Naracoorte, Newdegate, Launceston, Mingenew, Skipton, Tulloona and Yorke Peninsula.

Mike Ashworth inspects a stubble management trial

In the pipeline for 2016

- A field trial will look at the effect of stubble management practices on disease load. The stubble will either be burnt or treated with herbicide.
- New economic decision tools will be extended to growers and advisors, to help make more profitable decisions that also allow for good disease management.
- A new citizen science project will be launched. The project, Canola Rot WAtch, will see high school students participating in CCDM research, helping to provide samples for further study in sclerotinia stem rot. Mildew Mania and Stop the Spot will continue in 2016.

CASE STUDY: MILDEW MANIA

Mildew Mania is an agricultural citizen science project where WA schools are asked to grow barley to “catch” powdery mildew and send samples to researchers at CCDM for further investigation.

In 2015, 105 classes (2824 students) registered online and were sent experimental kits. CCDM researchers were able to genetically analyse a number of the samples received from across WA, providing a much better cross-section of where and how the pathogen may be changing.

Because of Mildew Mania, the research team are better able to keep track of the disease and watch for the development of new pathotypes, as well as ensuring resistant barley varieties retain their resistance.

Where the testing regime confirms a break down on plant resistance to powdery mildew, CCDM and GRDC will actively disseminate information to growers on which varieties are affected.

In December, CCDM researcher Nola D’Souza and Katanning farmer Mick Quartermaine visited one of the participating schools, Parkwood Primary School, to thank the students for their involvement and presented them with certificates.

Since the project’s establishment in 2011, more than 14,000 WA students from 220 schools have been involved. Because of its yearly success, the project will continue in 2016.

Year 5 Students of Parkwood Primary School with Katanning Farmer Mick Quartermaine and CCDM researcher Nola D’Souza

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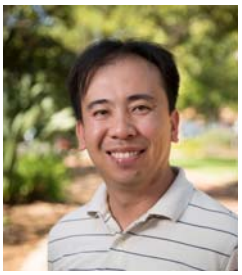

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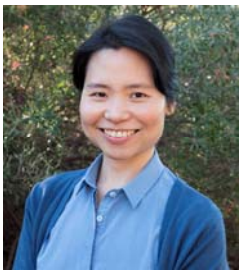

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OUT AND ABOUT
CCDM STAFF AT VARIOUS 2015 INDUSTRY EVENTS

John Noonan presents to growers at the Tulloona Field Day, northern NSW

CCDM participates at the AHRI/CCDM Crop Protection Forum

Mark Derbyshire inspects canola at the Stirlings to Coast Farmers Field Day

Megan Meates showcases CCDM at the Yorke Peninsula Field Days (SA)

CCDM discusses crop disease research at the More than Gumboots and Tractors teachers professional development day

Amir Abadi at the Skipton (VIC) Fungicide Resistance workshop

Amir Abadi talks about crop disease with West Dale farmer Daniel Bayley

King Yin Lui attends the Southern DIRT Spring Field Day

CCDM talks to growers at the Dowerin Field Days

Mike Ashworth discusses stubble management with the Liebe Group

Curtin and GRDC at the Topping Out Ceremony for CCDM's new agricultural facility

Centre for Crop and Disease Management

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

Curtin University