2017

Grains Research and Development Science Highlights 2015-17

Department of Agriculture and Food Western Australia

Department of Agriculture and Food

GOVERNMENT OF WESTERN AUSTRALIA

Grains

Research and Development

Supporting your success

Science Highlights 2015-17

Important disclaimer

Copyright

Accessibility

Copies of this document may be available in alternative formats upon request.

3 Baron-Hay Court, South Perth WA 6151
Tel: +61 (0)8 9368 3333
Email: grainscomms@agric.wa.gov.au
agric.wa.gov.au

1

Foreword and Royalties for Regions

2

Integrated Farming Systems Portfolio

3

Soil Productivity Portfolio

4

Crop Protection Portfolio

5 Genetic Improvement Portfolio

6 Field Research Services Portfolio

Investment in science and industry development key to profitable agrifood sector

It is an exciting time to be leading an agency responsible for supporting the state's agriculture and food sector — recognised by the Western Australian (WA) Government as one of the key areas for growth to contribute to the state's economy.

The successful WA agriculture sector of today has benefitted from significant long term investment by the State in science and industry development, with the cumulative benefits realised over a 20-30 year timeframe.

Department of Agriculture and Food, Western Australia has played a crucial role in defending existing industries from biosecurity risks that impact on productivity and market access, and in facilitating development of new and existing industries.

The world-class Research and Development (R&D) undertaken by the department has led to accelerated industry growth, improved community wellbeing and a more sustainable environment.

All our decision making and provision of information to clients is based on world-class science that strongly contributes to the government's vision and priorities for the sector.

Mark Webb
Acting Director General

Committed to international competitiveness and industry growth

Western Australian grain production and industry value has quadrupled over the past 30 years, despite declining winter rainfall, more frost and high temperature events, acidifying soils and increasing input costs. Strong evidence links this productivity growth to R&D that has delivered genetically superior varieties, better agronomic practices and more reliable farming systems.

Western Australian grain growers are innovators that rapidly adopt new technology which is increasingly sourced from a wider pool of national and global science, research and innovation.

Continuing to push the productivity frontier is not only critical to grower's profitability, it underpins the international competitiveness of our exports and value-adding opportunities for the Western Australian economy.

DAFWA's Grains R&D team aims to access and evaluate the most relevant new products and technologies under Western Australian grain growing conditions and to integrate the findings to support the rapid and appropriate adoption by Western Australian grain growing businesses.

Recent investment of $20 million through the "Boosting Grains R&D" Royalties for Regions initiative from the WA State Government is expanding our R&D infastructure and regional science capacity.

The Grains Research and Development Corporation (GRDC) is a critical partner, funding a large portfolio of projects with DAFWA that have been prioritised by WA grain growers.

DAFWA also partners with GRDC to lead the Grains Industry National Research, Development and Extension Strategy which plays an important role in connecting an increasingly large and diverse group of public and private R&D providers across Australia. This forum shares information and knowledge of R&D efforts nationally, which improves collaboration and speeds up the translation of a plethora of research outputs to commercial opportunities for grain growing businesses.

Dr Mark Sweetingham
Executive Director
Grains Research
& Development

Jason Moynihan, Director, Grains Business Development (second from left) and Portfolio Managers Dr Darshan Sharma, Kerry Regan, Dr Sally Peltzer, Dr David Ferris and Ian Pritchard (left to right).

Partnering for grain industry outcomes

DAFWA has strong research capacity across the grainbelt in areas of agronomy, soil management, crop protection, genetic improvement and farming systems. This enables us to deliver applied R&D ‘in the paddock’. The delivery and impact of our R&D is enhanced through collaboration with industry and grower groups, including linkages to fundamental grain science with universities and other research providers in WA, Australia and overseas.

During 2015 and 2016, DAFWA established new alliances with Murdoch University (Western Barley Genetics Alliance) and the University of Western Australia (UWA) (SoilsWest) strengthening our research capability in barley genomics, genetics and germplasm development in partnership with GRDC, and building our capacity and collaboration to integrate R&D across applied and core soil science. Another important development in 2016 was the appointment of Australian Grain Technologies (AGT) as the licensee to commercially develop DAFWA and GRDC’s jointly owned lupin breeding germplasm.

A number of key university and CSIRO collaborations strengthen academic and industry linkage and access to DAFWA regional research infrastructure and target environments. These include joint research projects with the Centre for Crop and Disease Management (CCDM) at Curtin University in crop pathology, UWA’s Australian Herbicide Resistance Initiative in weed management, Murdoch University’s Centre for Rhizobial Studies in legume nitrogen fixation and CSIRO in soil water and bio-economic modelling.

DAFWA also has a number of collaborations through national R&D programs, including the Australian National Frost Initiative, the National Oat Breeding Program, National Weed Management Program, National Invertebrate Pest Initiative, national crown rot, nematode and foliar pathogen collaborations comprising a National Disease Management Program and the More Profit from Crop Nutrition initiative. These national partnerships, reflecting the Grains Industry National RD&E Strategy, have been developed with substantial support from the GRDC and collaborating agencies.

DAFWA provides ongoing support to the Grains Industry Association of Western Australia (GIWA) and the Grower Group Alliance (GGA), two important industry groups addressing grain industry and grower needs. By helping to foster initiatives, such as the WA Grains Industry 2025+, our R&D programs can benefit from approaches that consider the needs of the whole of the grains supply chain.

Dr Robert Loughman
Director Grains Research and Innovation

Royalties for Regions: Boosting grains R&D

WA grain growers have significant opportunities to supply additional grain into expanding and changing markets in Asia and the Middle East, and increase the overall value of grain exports beyond $5 billion a year.

The Boosting Grains R&D project (Royalty for Regions) aims to increase on-farm grain productivity and profitability to enable WA grain growers to capitalise on expanding markets, and establish a regionally focused R&D institute to re-energise the performance and future development of local R&D capability.

The project is delivering new and upgraded regional research facilities and equipment to support field-based trials, and the validation of research in WA's specific conditions, climate and soils. These research facilities are designed for multipurpose applications and their usefulness will extend far beyond the life and scope of the project.

New employment opportunities have been created for early-career scientists across the grainbelt, with junior scientists teamed with more experienced researchers to strengthen professional development. A new PhD program also forms part of the development of grain scientists. Together, these capacity building initiatives will improve science depth and maintain research capability to address future grain industry challenges in WA.

Specific flagship research projects have been established to deliver on the key themes of more grain from less rain, lifting the yield ceilings, frost proofing the farm business and regional agronomy systems.

The flagship projects aim to enhance the delivery of localised R&D and address issues including: crown rot in oats; optimised seed coating techniques; early sowing of field peas; smart technology for pest and disease surveillance; developing better ways to sample and assess soil properties, powdery mildew management, slug and snail controls, frost management; crop protection and production agronomy; and genetic plant responses to soil moisture.

These projects will enhance the great work already being done by DAFWA, together with the GRDC, universities, grower groups and other partners throughout the grainbelt.

A more effective, flexible and enduring grains R&D business model will be introduced in support of these initiatives through the creation of a new not-for-profit entity that will conduct independent, commercially relevant R&D in partnership with the GRDC.

A state soil archive is currently being established at Muresk Institute to house more than 150 000 soil specimens that have been collected from around WA. These soil time capsules provide researchers with the opportunity to further analyse soil properties as technology advancements are made and new research techniques become available over time.

The Boosting Grains R&D project supports world-class grain science that will deliver solutions to local agronomic challenges, leading to increased grain productivity and exports, long-term profitability for grain growers, and broader economic benefits for the state.

Future plans focus on the formation of the new grains R&D entity in collaboration with the WA Government, GRDC and the WA grains industry.

Funding and collaborators

DRD Royalties for Regions, Office of Science, GRDC, GIG, Muresk Institute

HIGHLIGHTS

- Design and implement flagship research projects.
- Construct contemporary grains R&D infrastructure in Northam, complementing facilities in Merredin, Esperance and Geraldton with multipurpose application.
- Employ and develop early career scientists throughout the grainbelt.
- Establish the state soil archive at Muresk Institute, Northam.
- Lay foundation for future capability through a grains research PhD program.
- Implement a new delivery model for applied grains R&D

Science team

Jason Moynihan (Project leader), Dr Geoffery Anderson, Dr David Ferris, Dr Michael Francki, Chris Gazey, Dr Daniel Huberli, Svetlana Micic, Dr Sally Peltzer, Dr Craig Scanlan, Dr Dusty Severtsen, Dr Darshan Sharma, Geoff Thomas, Dr Ron Yates

Right: DAFWA Research Officer Dr Gaus Azam inspects soil samples in the soil archive facility at Muresk Institute in Northam.

Royalties for Regions: eConnected Grainbelt – Helping grain growers better manage risk

Technology is an important component to ensuring our state's agricultural sector remains internationally competitive.

DAFWA's eConnected Grainbelt project, a Royalties for Regions investment, is working to connect information across the grains industry to enable growers to make more profitable decisions tailored to their farm business.

The eConnected Grainbelt project is seeking involvement from growers, consultants and agribusiness to ensure decision support tools, systems and technologies meet the needs of the industry.

We are working with 14 grower groups and consultants who are hosting 11 eDemonstration sites across the grainbelt. Each site has been fully instrumented with an automatic weather station and soil moisture probes at no cost to the grower group ready for the 2016 growing season.

These sites provide a place where growers, consultants and industry can gather to learn about, compare and contrast all of the decision support tools, systems and technologies available for on-farm decision making. This technology will empower growers with information and decision making tools to manage risks and boost the profitability of their grain production businesses.

Grower groups that host the eDemonstration sites include the Corrigin Farm Improvement Group, Facey Group, Far East Agricultural Research Group, Merredin and Districts Farm Improvement Group, Mingenew–Irwin Group, South East Premium Wheat Growers' Association, Southern DIRT, West Arthur Trials Group, Stirlings to Coast Farmers, Gillamii Centre, West Midlands Group, Grainbelt Natural Resource Management, and Yuna Farm Improvement Group.

As well as developing decision tools, the eConnected Grainbelt project is opening up access to DAFWA datasets via application programming interfaces (APIs). This will allow third parties to incorporate DAFWA data, such as DAFWA's weather station data, into their own applications.

Funding and collaborators

DRD Royalties for Regions, GRDC

HIGHLIGHTS

- The state government has committed $10 million Royalties for Regions funding to the eConnected project to ensure our grains industry uses technology to remain internationally competitive.
- We are working with growers to ensure they have the skills and confidence to use technology and new tools for decision making, and ensuring tools are developed to meet their needs. End-user feedback has prioritised 12 decision tools for development.
- We are opening up DAFWA data to third parties through the development of application programming interfaces (APIs).

Science team

Tim Maling (Project leader), Dr Fiona Evans, Dr Kefei Chen, Alain Baillard, Neil Steventon, Sam Hassel, Katherine Davies, Tanya Kilminster, Dr Rebecca O’Leary, Alison Lacey, Brendan Nicholas, Janette Pratt, Chad Reynolds, Jeremy Lemon, Dr Ian Foster

Right: DAFWA Development Officer Katherine Davies checking a weather station at one of the eConnected sites.

DAFWA Research Officer Brenda Shackley discussing trial results with growers at a field day.

Integrated Farming Systems Portfolio

The integrated farming systems (IFS) team undertakes applied R&D to improve crop management practices for the major grain crops grown in WA.

Research activities include wheat, barley, canola and oat agronomy, early and dry seeding technologies, tactical break-crop and pasture-based cropping systems, seasonal forecasting and nitrogen fixation studies.

Our team is also actively building research capacity in crop protection and agronomy, and providing biometric support across R&D portfolios.

In 2015–16, $7.8 million was invested in R&D through the integrated farming system portfolio by engaging 44 staff on 15 projects across all cropping regions from Geraldton to Esperance.

The new knowledge, practices and decision support tools we have delivered help to underpin productivity gains across the grains industry.

In 2014–15, the gross value of agricultural production (GVAP) for wheat ($2.7 billion), barley ($889 million) and canola ($866 million), collectively contributed 56% of the total value of agricultural production in the state (ABARES). In 2016, around 7.5 million hectares were sown and a record harvest of 18.2 million tonnes was achieved.

The central plank of the IFS portfolio is agronomy of wheat, barley, canola, oats and pulses. A key focus includes developing regionally relevant management packages based on trials to evaluate genotype-by-environment-by-management inputs: particularly sowing rate and time, nitrogen fertiliser rate and timing.

Just some of the practical ways in which the IFS team supports growers with new knowledge includes: expansion of the MyCrop diagnostic tool to include individual apps for wheat, barley, canola, oat and pulses; development of the Flower Power tool to predict wheat flowering time and the risk of frost or heat stress; and distribution of the canola seed rate calculator to 2500 industry associates and 4500 grain growers.

The IFS team are committed to developing better agronomic packages in the face of increasing climatic, commodity and input price variability; and supporting growers with timely, tactical and locally relevant information and tools to improve agronomic decisions.

The team has initiated a series of trials across the grainbelt to evaluate the viability of early and dry sown crops. This will provide the evidence base to develop a 'traffic light' system to guide early sowing opportunities.

Collectively, our activities seek to provide growers and the grains industry with essential knowledge and decision support tools to improve the profitability of farm businesses by increasing crop production, reducing input costs and optimising the use of resources.

Dr David Ferris
Portfolio Manager

Canola as a tactical break crop

WA is the major canola growing state in Australia, with 1.17 million hectares sown in 2016.

Canola is increasingly popular in low to medium rainfall zones as a wider range of varieties become available and it maintains its competitive economic advantage over other break crops.

The tactical break crop agronomy project's canola management guidelines help to reduce upfront costs at seeding and lower seasonal risks. The project supports the expansion of canola production by conducting field trials, particularly in lower rainfall environments, to address key management issues, including identifying the optimum plant density and timing of nitrogen (N) inputs for open-pollinated, hybrid and RR (RoundupReady) canola.

Growing season rainfall in medium to lower rainfall zones is less reliable and its distribution more variable than higher rainfall zones where canola has been widely adopted over the past 10 years. We therefore need to develop agronomy packages for lower rainfall areas that minimise the risk of failed crop establishment and maximise gross margins, but retain the flexibility to manage economic risk by not committing too many resources upfront before a season's potential is clear.

Results show that seed of hybrid and genetically modified canola varieties can be sown at lower seeding rates and achieve similar yields to those sown at a typical 4–6kg/ha (80 plants/m^2), provided weeds are not an issue. This is partly due to better survival and emergence of hybrid seed (Table 1).

Table 1. Suggested target crop density for canola (plants/m^2). The higher density combats weed.

Rainfall zone	Hybrid	Open pollinated
250-325 mm (low)	20-25	30-40
325-450 mm (medium)	25-40	35-50
450-550 mm (high)	30-40	40-60

Another significant result (14 out of 16 trials) is that for the same total rate of N applied, the time of application had very little impact on yield. Typical low rainfall N rates of 25–30 kg N/ha applied as split, top-up or one application at seeding, four, eight or twelve weeks after seeding produced similar yield and oil content.

Collectively, results from our crop density and N management trial series have provided growers with the confidence to reduce upfront costs by reducing seeding rates and delaying their top-up N decisions until closer to flowering, if conditions early in the season are uncertain.

Ongoing research will address very early sowing, precision seeding, N timing, aphid management, in-crop herbicides and tolerance to residual herbicides and aluminium.

Funding and collaborators

GRDC, CSIRO, NSW DPI

HIGHLIGHTS

- We have developed a seed-rate calculator to guide sowing decisions. The calculator is easy to use and available online at agric.wa.gov.au
- Our canola management guidelines, based on consistent trial results, reduce upfront costs at seeding and lower the risks due to seasonal variability.

Science team

Mark Seymour (Project leader), Raj Malik, Martin Harries, Dr Bob French, Sally Sprigg, Jackie Bucat, Pam Burgess, Stephanie Boyce, Laurie Maiolo

Above: DAFWA Research Officer Mark Seymour, DAFWA Development Officer Jackie Bucat, and Technical Officer Stephanie Boyce in paddock of canola.

Below: DAFWA Research Officer Mark Seymour at canola density trials.

Local oats Durack, Williams and Bannister nourish growing global appetite

While WA oats are traditionally grown in medium to high rainfall areas, increasing international demand for oats, coupled with the release of high-yielding varieties Williams and Bannister, and most recently Durack, has led to the expansion of oat production into less reliable medium to low rainfall areas.

Oat agronomy research conducted by DAFWA is providing critical crop establishment and management information to support growers in adopting new varieties.

Trials have focused on identifying target sowing time dates, plant density and nitrogen rates for current varieties and breeding lines that are expected to be released from the National Oat Breeding Program.

The most suitable growing environments for the new varieties have been identified, with Bannister proving to be a better option than Williams in the lower rainfall environment. Durack is the earliest maturing oat variety suited for conventional sowing windows in medium-low rainfall areas or for delayed sowing opportunities in traditional (medium-high rainfall) oat areas.

Results have highlighted the need for growers to understand that varieties differ in their crop establishment and management requirements. Significant yield and quality improvements can be made when variety specific agronomy is applied.

The WA oat industry generates about $200 million for the state economy each year through the production of milled (rolled) oats for human consumption, and feed oats and oaten hay for livestock production.

New high-yielding varieties with improved disease resistance are encouraging the incorporation of oats as a break crop in the farming system. In paddocks with a background of cereal root disease, oats can provide an excellent break.

The major markets for Australian milling oats are Mexico, North Asia, South-East Asia and South Africa, with demand also increasing in China.

Funding and collaborators

GRDC, SARDI, Consult Ag

HIGHLIGHTS

- Increasing demand for WA oats, coupled with new high yielding varieties, is providing an excellent opportunity for expansion of the oat industry.
- Recently released varieties have set the yield and quality benchmarks for the milling oat industry, and have strengths in different rainfall regions.
- Variety specific agronomy is required to achieve yield and quality of new milling oat varieties.

Science team

Georgie Troup (Project leader), Raj Malik, Mark Seymour

Above: DAFWA's oat agronomy researchers with principal collaborators from ConsultAg and SARDI.

Below: National Oat Breeding team members from DAFWA and SARDI at the 2016 release of Durack with GRDC Breeding Manager Tom Giles (third from right).

The truth about seeding rates in barley

Some believe that the higher the seeding rate of barley, the lower the quality of the grain. However, DAFWA researchers have found that seeding rate only has a small impact on grain quality, even though the absolute change in quality does vary with variety.

A key component of the barley agronomy project is to help growers become more aware of the best seeding rates for their chosen variety to maximise yield, grain quality and crop profitability.

Ideally, it is better to think of seeding rate in terms of plants per square metre rather than in kilograms per hectare.

The reason for this is that the weight and size of seed differs across all varieties. So 1 kg of seed from one grower's seed source could be equal to 22,000 kernels (at 45 mg per kernel of grain) whereas another may be equal to 28,000 kernels (at 35 mg per kernel of grain).

Surveys in 2013 and 2015 found that only 15% of growers counted the number of established plants per square metre. Growers know their seeding rate in kg/ha but not how this translates into establishment or target density in plants per square metre.

The group collated recommendations for target plant densities from 33 barley field trials conducted between 2012 and 2014.

We measured establishment plant density, grain yield and quality, and did an economic analysis (including seed costs) to calculate changes in profit as plant density increased.

Ongoing work is focused on lower yielding environments and new malt barley varieties for which we don't yet have plant density recommendations.

MALT / FOOD 110-130 plants/m^2	MALT / FOOD 150-180 plants/m^2	FEED 180-220 plants/m^2
• Baudin	• Bass	• Compass
• Commander	• Flinders	• Fathom
• Granger	• Hindmarsh	• Litmus
• Scope CL	• La Trobe	• Mundah
		• Oxford
		• Rosalind
		• Spartacus

Figure 1. Suggested target plant density per square metre by variety.

Key findings:

Barley sown at a density of 50 plants/m^2 displayed a yield penalty of 10% compared to barley sown at 100 plants/m^2. A further 5% yield could be gained by increasing plant density above 100 plants/m^2.

- While increasing plant density can decrease grain weight, hectolitre weight, grain protein, grain brightness, and increase screenings, the absolute change in grain quality was small (but did vary with variety).
- The target plant density that maximised profit differed with variety (Figure 1).
- Growers can calculate the most profitable seed rate (in kg/ha) for each variety they grow by determining 1000 grain weight and germination percentage and by knowing the target plant density for each of their varieties.

Funding

GRDC

HIGHLIGHTS

- Growers need to think in terms of plants/m^2 and use grain weight to convert target density into a seeding rate for kg/ha.
- Varieties react similarly to increasing plant density for grain yield; while the impact on grain quality is small, it varies with variety.
- Recommendations for target plant densities were included in the 2016 Barley Variety Factsheets and the MyCrop Barley Selector.
- Early adopters of the recommendations have reported increased profits from their paddocks.

Science team

Blakely Paynter (Project leader), Georgia Trainor, Sue Cartledge, Raj Malik, Rod Bowey, Jeremy Curry, Rachel Brunt

Above: DAFWA Development Officer Georgia Trainor discussing trial results at Mingenew field day.

Below: Barley seeding rate trials.

DAFWA Research Officer Jeremy Curry in DAFWA's purpose built rainfall simulator.

Rating the risk of pre-harvest sprouting

Pre-harvest sprouting (PHS) (when wheat in a grain head germinates prematurely before harvest), is a major quality issue in WA. PHS is mainly caused by rainfall and high humidity at grain maturity (that is, a 'wet harvest').

But even before the visible signs of germination appear, alpha-amylase (a germination enzyme) begins to break down starch in the seed which reduces grain and flour quality.

Affected varieties risk not meeting grain receival standards, as sprouted grain is often downgraded to feed, shaving profits from each tonne of grain delivered.

Wheat varieties differ genetically in their susceptibility to PHS. The combination of genotype plus environmental factors influence the levels of sprouting observed in the field.

Seed dormancy alone is inadequate to rate susceptibility of different varieties to PHS, as the level of dormancy is strongly influenced by environmental conditions during grain fill. Furthermore, morphological characteristics such as awn length and glume tenacity also influence PHS as these traits can affect the amount of moisture that grain heads absorb. Thus, the study of PHS susceptibility and the traits that increase or reduce the risk of PHS is complex.

This project aims to provide relative ratings of the risk of PHS in current and future wheat varieties. The methodology for this research is based on a series of trials and evaluation of PHS under controlled moisture conditions in a purpose-built rainfall simulator.

After exposure to different moisture treatments, the falling number results for each variety, together with dormancy (germination index) data, are used to assess each variety for PHS risk. By increasing our knowledge and awareness of the relative sprouting risk of currently available wheat varieties, growers will be able to choose less susceptible varieties and implement management strategies to reduce their risk of downgrading due to PHS in any given year.

Field trials and the improvement of protocols to assess PHS risk are continuing.

HIGHLIGHTS

- This research assesses differences between PHS susceptibility of current and future wheat varieties.
- Each year, breeders submit several of their most promising lines for inclusion in the trials. The results are communicated back to the breeding companies, as well as to growers and industry, upon their commercial release.
- Greater knowledge of PHS susceptibilities of particular varieties helps growers to choose the most suitable varieties and strategies to reduce the risk of downgrading.

Science team

Jeremy Curry (Project leader), Rachel Brunt, Dr Dion Nicol, Christine Zaicou-Kunesch, Brenda Shackley, Dr Bob French, Mario D'Antuono

Funding and collaborators

GRDC, GXE Crop Research

DAFWA Research Officer Doug Abrecht discusses the impact of water deficit on ear length in wheat at Merredin Field Day.

Dry sowing strategies: the quiet revolution in WA farming systems

Opportunities for successful cropping in low rainfall areas in WA have been identified by a research project examining the risks associated with dry seeding.

Sowing strategies, such as dry seeding and early seeding, aim to get a larger proportion of crop established earlier in the season. However, this potentially exposes dryland crops to water deficit and soil temperatures that can kill or stress seed or seedlings.

Understanding the impact of environmental conditions (early in the growing season) on grain yield and quality, underpins development of new strategies and practices to manage crop establishment in large dryland cropping programs.

The imperative for establishing crops earlier is to maximise the length of the season for crop growth while moderating exposure to water deficit and high temperatures at the end of the season. But filling grain earlier in spring also has contingent risks, including exposure to frost.

More than half of most cropping programs are sown in soil conditions moist enough to allow seeds to emerge at favourable times and make efficient use of seasonal conditions. However, such sowing strategies inevitably place great reliance on seeding capacity (ha/day) and logistics to avoid late sowing or emergence, and associated yield penalties, in a significant proportion of a cropping program.

Seeding practices that are not limited to conditions suitable for seeding emergence, such as dry sowing, provide for more efficient use of seeding machinery, time and labour, and may remove barriers to increasing the size of cropping programs in a farm business.

Research conducted by the dry sowing project has found that while the risk of seed and seedling death or damage in dry sown crops is moderate, the impact of dry sown crop on the timing of seedling emergence and productivity of cropping programs is positive.

HIGHLIGHTS

- Sowing crop into soil that is not wet enough to support seedling emergence gets a larger proportion of the cropping program established earlier at the expense of some seed and seedling death or damage.
- The impact of seedling death or damage on crop production is small compared to the impact of the yield penalty for later (mid-June) seedling emergence.

Science team

Dr Doug Abrecht (Project leader), Dr Darshan Sharma

Funding and collaborators

GRDC, WANTFA, CSIRO

Reap benefits with early sowing

How early is too early to begin sowing wheat crops? This has been a burning question on the minds of many WA growers as they seek to balance the opportunity presented by early rains in autumn with the risk of frost and heat stress later in the season.

Yield losses in excess of 0.2–0.4t/ha for every 1°C rise in average temperature at flowering and grain fill can equate to a loss of income of $40–80/ha. This risk can potentially be avoided by sowing earlier with suitable varieties. However, knowledge of suitable varieties — those varieties timed to flower when the risk of frost and heat stress are low — is limited.

Field trials are pushing the boundaries for early sowing of wheat. Currently, there is only limited research data on the yield of wheat crops when sown earlier than 25 April; the vast majority of R&D has focused on May sowing dates. The tactical wheat agronomy project is addressing this void by evaluating the performance of early sown crops when opportunities arise.

The potential benefits and suitability of longer wheat maturity lines (for very early sowing opportunities) is also being assessed and will highlight the traits needed for variety development in the future.

In 2015, this research was enhanced by a fast-tracked early seeding project funded by GRDC's Regional Cropping Solutions Network (RCSN). The trial evaluated the agronomy of wheat varieties at three sowing times in the north-eastern agricultural region.

Results suggest that wheat and canola are suitable options for early to mid-April sowing when the right weather conditions occur. However, sowing before the traditional seeding window (that is, before 25 April) is not without risk. Overall, the yield of very early sown crops were similar or less than crops sown in the ideal sowing window; and lower seeding rates of wheat did not influence yield or quality compared to normal seeding rates when sown in early April.

However, growers may not see a flat or reduced yield response to very early sowing as an issue. Instead, the early sowing window allows them to get crops out of the ground and reduces the risk of dry spells leading to a lack of future sowing opportunities. This research project is providing a platform for discussion at a regional and state level on the value of early sowing in WA.

Funding and collaborators

GRDC, Yuna Farm Improvement Group, Mullewa Dryland Farming Initiative, West Midlands Group, Merredin Dryland Farming Group, FEAR, SEPWA

HIGHLIGHTS

- Early sowing can get crops out of the ground and reduce the risk of inadequate sowing opportunities in May due to dry spells.
- Current commercial wheat varieties are exposed to the risk of frost and other grain quality issues (like staining and sprouting) when sown early.
- Highest wheat grain yields are not always achieved at the earliest sowing opportunity.
- Very early sowing opportunities (pre-Anzac Day) need a more suitable variety for the WA environment.

Science team

Christine Zaicou-Kunesch (Project leader), Jeremy Curry, Rachel Brunt, Brenda Shackley, Rod Bowey, Dr Dion Nicol, Georgia Trainor, Bruce Haig, Melaine Kupsch

Above and Below: DAFWA Research Officer Christine Zaicou-Kunesh with growers at a field day.

 Martin Harries in early sown canola trial at Wongan Hills.

Agronomy for early sown canola

Ongoing research has found early sowing is a key element to maximising yield in the northern grainbelt of WA.

Through the tactical break crop agronomy project, we have refined the agronomy for early sown canola crops. Research in 2015 reinforced that sowing around mid-April is critical to maximising yield. When compared to plots sown in mid-April, plots sown at the end of April at Binnu suffered a yield penalty of 40 kg/ha/day.

Trials evaluating new canola varieties showed little difference between the responses of the different season length varieties to delayed sowing: all varieties suffered a large yield penalty when sown in late April compared to those sown in early or mid-April. These preliminary results from the northern region showed that growers should use the highest yielding variety for their area, rather than try to match variety season length to sowing date.

While early sowing is a key to maximising canola yields it also comes with added risks. In particular, the crop is more likely to experience hotter temperatures at sowing and potentially a long period without rainfall following sowing.

The project has identified establishment of canola as a major issue and have implemented a series of field and laboratory trials to investigate the effects of seed type (open pollinated versus hybrid), seed size, sowing depth and environmental conditions on establishment.

With early sowing, there also comes an increased risk of pest insects and foliar diseases. The project is working with DAFWA entomologists and pathologists to refine management packages for the major insect and fungal pathogens of canola.

HIGHLIGHTS

- Early sowing is the key to maximising canola yield.
- Yield declines of 40 kg/ha/day were recorded following later planting in some trials.
- We need to improve canola establishment in dry warm conditions.
- Insect and disease challenges increase with early sowing.

Science team

Mark Seymour (Project leader), Martin Harries, Dr Bob French, Stephanie Boyce, and Laurie Maiolo

Funding and collaborators

GRDC, NAG

Precision seeding of canola

DAFWA's Tactical break crop agronomy project has examined whether row cropping machinery (such as precision planters) could be used to enhance canola production at low seeding rates. This machinery places the seed at equal distances within the crop row, minimising competition between individual plants.

Previous studies in both WA and Canada showed that canola (and lupin) yield could be improved when plants were sown with a more uniform distribution.

Second, seed costs for canola production have increased for growers who have switched from open pollinated to hybrid varieties. Therefore, using better seed placement methods may enable seed rates to be lowered without compromising yield.

Two trials were sown in the northern agricultural region (at Ogilvie and Binnu) using the variety Hyola 404RR. The machine used had seven planter boxes spaced 50 cm apart. There were four treatments of different seeding rates to test very low seed rates of 0.3, 0.5, 1.0 and 2.5 kg/ha.

The trials yielded over 2t/ha, providing further evidence that canola can be successfully grown at these wide row spacings. At both sites, there was a trend of decreasing yield from high to low seeding rate, although the reduction in yield was less than expected.

When examining profit at the Binnu site, gross margin of the 2.5 and 1.0 kg/ha treatments were similar, indicating that $47/ha could be saved in up-front costs without impacting upon final profit. At this site, using seeding rates lower than 1.0 kg/ha reduced gross margin. At the Ogilvie site, gross margin was similar for the 2.5, 1.0 and 0.5 kg/ha treatments — again suggesting that up-front costs could be reduced without impacting profit.

The results of this work suggest that precision sowing may enable sowing at lower seeding rates and that this concept is worth pursuing with further research. The machinery is also being tested by a select group of growers to see if it is viable on a commercial scale.

Funding

GRDC

HIGHLIGHTS

- At very low seed rates, canola still yielded well, showing that more accurate seeding may enable growers to reduce up-front costs.
- Canola can be grown at wide row spacing (50cm).
- This opens the option of using row cropping machinery such as a precision planter.

Science team

Mark Seymour (Project leader), Martin Harries, Sally Sprigg, Stephanie Boyce, Laurie Maiolo

Right: DAFWA Research Officer Martin Harries in precision seeding trials.

Left: The Agricola Italiana K series pneumatic precision drill used to sow the trials.

New technology for early sown field peas

Many growers find it critical to get their crops sown as early as possible to combat a possible dry finish in spring. However, this is not considered a practical option with field pea. There are major reasons that deter growers from sowing early, including the increased chance of failed nodulation, exposure to fungal diseases (black spot and root rots) and lack of weed control.

Nonetheless, sowing field peas earlier in the growing season could be a viable option and needs to be explored, especially as penalties in field pea yield from dry and unseasonably hot conditions in spring are becoming a regular occurrence in southern Australia.

The project aims to highlight better agronomic techniques for early sowing field peas while overcoming problems related to early sowing. Studies will ultimately be based on yield, but importantly focus on the pea-rhizobia symbioses including measurements of nodulation and nitrogen (N) fixation.

The plants will be inoculated by granules allowing an opportunity to evaluate new fungicides applied as seed dressings or, alternatively, foliar fungicides will be sprayed post-sowing to control black spot.

We are currently evaluating a range of herbicide sprays on earlier sown field peas for their efficacy on weed control and their effects (if any) on N fixation.

Furthermore, the project is assessing new elite experimental acid-tolerant rhizobium strains to measure if they fix more N and result in higher pea yields than the commercial rhizobial inoculants.

Funding and collaborators

GRDC, MU (CRS), Curtin University (CCDM)

HIGHLIGHTS

- The research aims to provide agronomic techniques so that growers can successfully and reliably sow field peas earlier in the growing season.
- Applications of herbicides and fungicides in crops of field pea will be evaluated for effects on nodulation, N fixation and seed yield to identify the better options for growers.
- The project will assist in deciding if the new elite experimental pea nodulating rhizobial strains should replace current commercial inoculants group E and F.

Science team

Dr Ron Yates (Project leader)

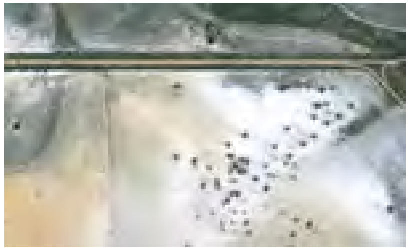
Left: Dr Ron Yates inspects field pea from a rhizobial inoculant plot trial established at the DAFWA Katanning Research Station, 2016.

Right: Dr Ron Yates inspects eight-week-old field pea plants from a rhizobial inoculant plot trial established at the DAFWA Katanning Research Station, 2016.

Perennial grasses boost productivity of deep pale sands

Sandy soils with low fertility are common in the northern agricultural region (NAR). These soils support sparse annual pasture and are occasionally cropped. The paddocks generally have low water-holding capacity and low productivity, with limited ground cover that predisposes them to wind erosion, groundwater recharge and associated dryland salinity.

In an effort to stabilise these soils and to provide out-of-season fodder for grazing enterprises, many farmers are using the land to sow subtropical perennial grasses.



Left: Satellite image of paddock prone to wind erosion at Arrino. Right: The same paddock stabilised by sowing 25 ha of subtropical perennial grasses.
(Photos: Imagery © Western Australian Land Information Authority, Landgate, 2015; Apple Maps, 2015)

The subtropical perennials become dormant during the winter so there is scope to grow crops while maintaining summer groundcover. This practice, known as pasture cropping, increases the production options from deep pale sands.

DAFWA, with support from local grower groups, growers and agronomists, ran a series of trials looking at the potential of pasture cropping in the NAR and to establish guidelines that can assist growers. The trials have shown that most crops can be grown successfully in conjunction with an established perennial pasture.

Perennials require additional inputs of N to fully utilise out-of-season rainfall. Consequently, the project looked at pasture cropping with legume crops and pastures that can help supply the required N. Lupin and serradella trials at Moora, Dandaragan and Mingenew have shown that there is little impact from competition from the perennial grass, lupins in particular being very competitive when planted in the established perennials.

Above: Response of perennial grasses to a nitrogen test strip at Dandaragan.

Lessons learnt from the perennial trial work in the NAR are now being tested in the sandplain soil on the south coast between Albany and Esperance.

Funding and collaborators

GRDC, Evercrop, CSIRO,
West Midlands Group, MIG, Agvivo

HIGHLIGHTS

- Subtropical perennial species provide feed into summer and respond to early breaks and summer storms while protecting the soil surface from wind and water erosion.
- An over-sown annual crop provides either a grazing opportunity or a harvestable grain crop during winter.
- Lupins and annual serradella pasture provide a good pasture cropping fit as an added income source and to supply N to perennial pastures.

Science team

Dr David Ferris (Project leader), Christiaan Valentine, Perry Dolling

Right: Harvesting a barley crop sown over suptropical perennial grasses at Moora.

MyCrop: free paddock diagnostics at your fingertips

Growers and agronomists now have a powerful suite of tools to assist diagnosis of production issues in wheat, barley, canola, lupins, oats and field pea crops. DAFWA has produced five MyCrop apps covering the most common constraints found in WA broadacre crops.

The free apps can help quickly identify problems based on real-time crop and paddock symptoms. They contain hundreds of high-quality images and fact sheets on major crop disorders, including a broad range of diseases, pests, nutrient deficiencies, herbicide damage symptoms and other management and environmental production issues.

A simple diagnostic key lies at the heart of the MyCrop apps. Growers or their advisers can be standing in a paddock and use the tool to identify disease, pest and other production issues affecting the crop. It is also a valuable education tool, offering young agronomists and agricultural students a centralised source of crop production information.

MyCrop integrates decades of agronomy, entomology and pathology research. Once downloaded, the apps can be used without the internet, functioning in the absence of mobile data networks. They are available for download on Android (Google Play) and iOS (Apple iTunes) devices.

Bundled within the MyCrop apps is a range of supporting tools:

- PestFax Reporter — allows users to directly report the occurrence of pests and diseases to DAFWA.
- CropCheck — contains information about when and how to monitor crops to ensure maximum crop productivity.
- The MyEconomic Tool — helps users consider the financial impact of treating crop constraints and compares different treatments.

There are also variety selector tools in the wheat and barley MyCrop apps.

Funding and collaborators

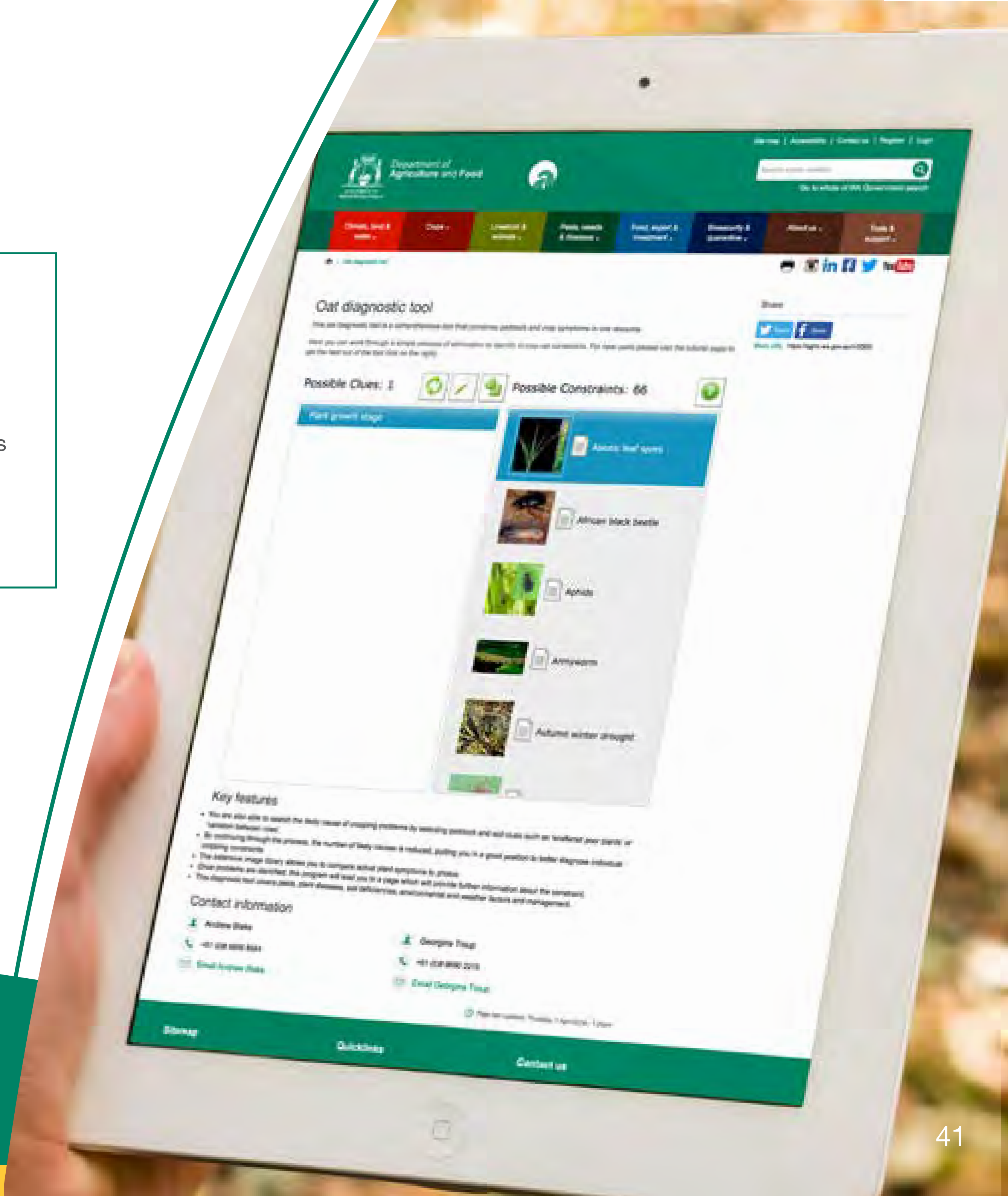
GRDC, DAF Qld, DEDJTR

HIGHLIGHTS

- The apps integrate extensive DAFWA research into wheat, barley, canola, lupins, oats and field pea agronomy.
- The diagnostic keys, including images and fact sheets, are also available on the DAFWA website as online tools.
- Variety selectors for wheat and barley crops are embedded in apps.

Science team

Andrew Blake (Project leader), Dr Sally Peltzer, Kelly Ryan



Right: The MyCrop Oats mobile application.

Left: DAFWA Research Officer Dr Sally Peltzer demonstrating MyCrop at a field day.

Flower Power: intelligent guide for wheat variety and sowing time decisions

If there are no flowers there can be no fruit (grain). Flowers are delicate and sensitive to extremes in temperature—thousands of dollars can be made or lost as a direct consequence of the environmental conditions experienced by flowering wheat crops. DAFWA's wheat agronomy project has developed an online tool (Flower Power) to help growers select the best varieties and sowing time for their region to minimise the risk of frost and heat stress during flowering.

The tool can predict the flowering time of up to three wheat varieties in up to three locations at a time and offers growers the ability to compare their chosen varieties at the same or different sowing times. Growers can use Flower Power to assess whether their chosen variety will stand up to both frost and heat and whether their sowing time is giving them the best opportunity to maximise profit.

The tool aims to encourage growers to minimise the risk of frost or heat stress by spreading sowing date and selecting a few varieties across their enterprise.

In 2016, Flower Power was updated to include 10 new wheat varieties including Bremer, Cobra, Corack, Emu Rock, Grenade CL Plus, Hydra, Justica CL Plus, Supreme and Trojan. In addition, 10 locations, including Corrigin, Kojonup and South Stirlings, were added to the existing 25 locations.

The addition of new varieties and locations will make the tool more accessible and relevant to growers. The enhancements to the model will allow growers to consider whether the flowering dates of newer varieties complement their farming system.

Many WA growers have used Flower Power since it was developed five years ago. In 2016, the webpage received more than 2200 views with growers keen to find out the effect that the early season break and subsequent early sowing of wheat will have on the flowering times of their wheat paddocks.

Flower Power uses a statistical model (called DM) that includes a vernalisation component in addition to photoperiod and temperature components, the three biological drivers of reproductive growth and development in wheat.

DAFWA scientist Darshan Sharma and Senior Biometrician Mario D'Antuono developed the DM model using observational data collected since 2006.

Funding

GRDC

HIGHLIGHTS

- Flower Power assists growers to make the best variety choice for their sowing time and environment by predicting flowering time and the risk of frost or heat stress.
- The online tool allows growers to compare varieties across sowing times and locations.
- The Flower Power tool has been updated to include 10 new varieties, including Bremer and Grenade CL Plus, and 10 new locations.

Science team

Christine Zaicou (Project leader), Jeremy Curry, Rachel Brunt, Brenda Shackley, Rod Bowey, Dr Dion Nicol, Dr Bob French, Georgia Trainor, Bruce Haig, Melaine Kupsch, Dr Darshan Sharma, Mario D’Antuono

Right: DAFWA Research Officer Jeremy Curry, Development Officer Georgia Trainor and Technical Officer Rachel Blunt with Charles Roberts (second from left) in a wheat crop at Dandaragan.

Understanding the season using data and technology

Technology is vital to ensuring our State's agricultural sector remains internationally competitive. The eConnected Grainbelt project is working to connect information across the grains industry to enable growers to make more profitable decisions tailored to their farm business.

One component of the project is developing electronic decision tools to help grain growers and their consultants 'play the season' using up to date information on growing season conditions.

The Rainfall to Date tool shows how much rainfall has fallen from the start of the grain growing season, and what can reasonably be expected for the remainder of the season.

The Soil Water tool shows the amount of soil water accumulated from the start of summer through the growing season. It uses a more sophisticated approach than the Rainfall to Date tool that models how rainfall moves through different layers in the soil and accounts for water loss from evaporation and crop use.

The Potential Yield tool uses seasonal rainfall and decile finishes calculated from historical data to calculate the maximum wheat yield possible in the absence of any constraints other than rainfall.

The Seasonal Climate Information tool shows maps of seasonal rainfall forecasts that are updated monthly during the growing season, as well as soil water, potential yield and frost risk maps.

The Weather Stations tool shows up to date weather information collected by DAFWA's network of 160 automatic weather stations.

The Extreme Weather Event tool shows real-time information about the location and severity of frost and heat stress events as they occur.

A Yield Prediction tool (that can be fine-tuned to a farm or paddock using historical yield data) and a Fertiliser Rates tool (that will show the effects on yield of nitrogen, phosphorus and potassium applications) are due in 2017.

Web site links:

eConnected Grainbelt
agric.wa.gov.au/r4r/econnected-grainbelt

Decision tools
agric.wa.gov.au/climate-land-water/climate-weather

Funding

DRD Royalties for Regions, GRDC

HIGHLIGHTS

- Decision tools developed by the project use near real-time weather data to provide information to help growers 'play the season' as it happens.
- The tools help address decisions about when to sow, how much fertiliser to apply at different times during the season, and how to best manage weeds, diseases and pests.
- User feedback on decision tools developed by the project will allow the tools to be updated to ensure they provide the most useful information in easy to use formats.

Science team

Dr Fiona Evans (Project leader), Tim Maling, Dr Kefei Chen, Alain Baillard, Neil Steventon, Sam Hassell, Katherine Davies, Tanya Kilminster, Dr Rebecca O'Leary, Alison Lacey, Brendan Nicholas, Janette Pratt, Chad Reynolds, Jeremy Lemon, Dr Ian Foster

Right: DAFWA Development Officer Katherine Davies demonstrating the extreme weather tool.

DAFWA's Soil Productivity Portfolio team.

Soil Productivity Portfolio

Soil constraints are estimated to cost growers more than $1 billion annually in WA and the benefits that can be realised through amelioration or management are significant.

The soils are often sandy and prone to acidity, compaction, nutrient deficiencies or toxicities and water repellence. Sodicity and transient salinity are common on heavier soil types. Key soil constraints affect the ability of roots to access water and nutrients. Our research is aimed at addressing these constraints in order to maximise water and nutrient use efficiency by plants, which can be as low as 50%.

It is estimated that acidity affects 70% of topsoil (~11m ha) and 50% subsurface soils (~5m ha) across the WA grainbelt. Approximately 75% (~12 m ha) are affected by subsoil compaction, 62% (~10 m ha) by subsoil sodicity, 11 % (~2 m ha) by transient salinity, and 11% (~2 m ha) by water repellence.

In 2015/16, $7.6 million was invested in R&D through the Soil Productivity portfolio by engaging 28 staff on 15 projects across all cropping regions from Geraldton to Esperance. Much of the soil research work is conducted at the farm scale with the assistance of growers. More detailed investigations use the department's trial support staff and small plot equipment, or are achieved through partnerships with universities, CSIRO and agribusiness.

Current research projects are focussed on amelioration and management of constraints through soil inversion techniques (mouldboard ploughs, rotary spaders, offset discs and disc ploughs); the addition of clay, lime, gypsum, wetting and other remedial agents; deep ripping and controlled traffic farming (CTF) systems, more effective use of nutrients and better fertiliser recommendations, and improved mapping and spatial detail of soil information to support farm business decisions.

Our team work collaboratively across research projects to achieve significant benefits by addressing multiple constraints at the same time. The Soil Constraints West group, which provides oversight and guidance in our R&D activities through an external steering committee, provides strong support for the collaborative approach.

Further, the Soil Productivity Portfolio group has strong linkages and in many cases joint projects with the universities, CSIRO, industry and grower groups. Most recently a new agreement has been established between DAFWA and UWA – SoilsWest – which will help build scientific and research capabilities to develop the long-term future of soil science in WA.

The R&D activities carried out by the group are showcased in the following pages and concentrate on innovative methodologies to assist growers to understand and effectively manage their soils. The research aims to develop viable economic solutions to soil constraints that show good return on investment.

Kerry Regan
Portfolio Manager

Collaboration generates abundant opportunities for tackling repellent soils

The combined forces of three universities, the CSIRO and leading grower groups have created an abundance of opportunities for the DAFWA-led GRDC research project into soil water repellence.

For crop production, the consequences of water repellency can be huge. Repellency can stress plants from the outset, resulting in poorer yield quality, run-off, loss of nutrients and poor weed control.

Together with the CSIRO and Murdoch University, we are examining the chemistry and nature of water repellence and how it impacts on crop growth, as well as researching a wide range of practical management techniques and their agronomic implications.

Understanding the chemistry and variability in expression of water repellence will help us to target management practices effectively. For example, recent research into soil wetters has found they can be very effective on repellent forest gravels and that some products can also work well when used in formulations with other liquid fertilisers and banded near the seed.

DAFWA project researchers have also collaborated with Australia's leading agricultural research engineers at UniSA to better understand and improve the use of strategic tillage implements, such as mouldboard and one-way ploughs, to better overcome a range of soil and agronomic constraints.

The project has had a leading role in helping develop capacity in future soils research by appointing three PhD students, two post-doctorates and two new DAFWA soils research positions, at Geraldton and Esperance.

Providing Murdoch University and UWA PhD students with an opportunity to work in close collaboration with DAFWA gives them the capacity to network with and understand the broader issues being faced by grain growers, to benefit their research and communication.

Partnerships with four leading grower groups across the grainbelt also provide opportunities for grower-focused communication, local demonstrations and a vital conduit for feedback and knowledge from industry back to the researchers.

New research will develop a better understanding of the chemistry of water repellence on a range of soil types, how it is distributed within paddocks and its impact on the availability of nutrients both in space and over time.

Ongoing research on management options on a range of soil types and environments will provide improved clarity for growers to confidently implement effective management practices.

Funding and collaborators

GRDC, CSIRO, MU, UniSA, West Midlands Group, SEPWA, MIG, SouthernDIRT

HIGHLIGHTS

- Extensive collaboration with universities is providing opportunities to train soils researchers and undertake fundamental research into understanding the water repellence problem, its consequences and management.
- Research results show that amelioration of strongly repellent soils can compound long-term benefits through:
  - » improving establishment
  - » reducing other soil constraints
  - » enabling more efficient use of water and nutrients
  - » reducing wind erosion risk
  - » enhancing weed control.

Science team

Dr Stephen Davies (Project leader), Giacomo Betti, Dr Paul Blackwell, Chad Reynolds, Joanne Walker, Dr Geoff Anderson, Dr Craig Scanlan, Glenn McDonald, Grey Poulish, David Hall, Tom Edwards

Right: DAFWA Research Officer Steve Davies discusses the challenges of growing crops on a water repellent forest gravel soil near Kojonup.

Clay: the soil solver for water repellence?

Water repellent soils are a major production constraint on many sandy and gravelly textured soils across WA. These soils are challenging to establish crops and achieve adequate weed control. Often the only way to correct this water repellence is by applying and incorporating large amounts of clay.

The practice of claying, which incorporates clay-rich subsoil into sandy topsoil either by clay spreading or delving, is one of the most effective methods to correct water repellence in the long term. It has been used by some growers in Australia for more than two decades.

By mixing clay into water-repellent sand, soil wettability improves significantly and dry patches (even after heavy rains) occur less frequently. Crops establish better and plant growth improves. Clay also benefits the soil by increasing its capacity to hold water and nutrients and reducing the risk of wind erosion.

Over 10 million hectares of agricultural land is affected by water repellence in the south-west of WA alone. We assess that claying will be an important corrective to repellent soils in the grainbelt in the long term, and in the drier central and northern regions in particular.

Growers in WA have been slow to adopt claying. This is partly due to the high initial costs of claying and partly because early anecdotes implied the risk of yield loss. The practice is limited and still perceived negatively by some growers.

As part of the GRDC-funded water repellence project, DAFWA initiated new long-term trials in 2016 to assess the practice under local conditions.

To account for different soil types and climates, three trials have been established — clay spreading at Badgingarra and Moora (deep sands and sandy gravel soils), and clay delving at Esperance (texture-contrast soil).

All trials have been designed to compare different rates of subsoil clay combined with different tillage methods for its subsequent incorporation into the topsoil (spader, offset discs, one-way plough) in the same paddock.

The aim of the trials is to better evaluate the benefits of adding subsoil clay to remediate repellent soil and improve crop establishment.

R&D activities will focus on two main aspects:

- economics – by comparing the cost-effectiveness of the treatments over a four-year period
- efficiency – by collecting data at different stages of plant growth to measure the impact of the treatments on soil water and nutrient availability.

Future work will focus on fine tuning the most cost-effective claying practices outlined by the results of the current trials. At the completion of the trials, we aim to produce best-practice guidelines for growers interested in claying.

Funding and collaborators

GRDC, West Midlands Group, SEPWA

HIGHLIGHTS

- Findings are likely to promote clay spreading and delving to manage water repellent soils.
- We aim to analyse the cost-effectiveness of combinations of clay rates and different incorporation methods.
- The project will also evaluate clay spreading on water-repellent gravel sands and clay delving on texture-contrast soils.

Science team

Dr Stephen Davies (Project leader), Giacomo Betti, David Hall, Chad Reynolds, Joanne Walker

Above: DAFWA Research Officer Giacomo Betti collects subsoil clay samples to determine the rates of clay spreading.

Below: Clay spreader in action at the Moora trial.

Coating technology - water repellence and soil fertility

New coating technology for seeds and fertiliser granules is being explored to protect seeds from adverse field conditions and environmental stress.

The research is evaluating the dual concepts of coating seeds with a surfactant and water-absorbing polymer to overcome water repellence, and applying an elemental sulphur coating to phosphate fertilisers for overcoming sulphur deficiency.

The advantage of coating technology is that the amendments in the coatings are situated close to the growing seedlings, which can improve efficiencies and reduce application costs.

We are evaluating two seed-coating substances — a commercial water-absorbing polymer and a soil surfactant. These seed coatings are being tested to improve crop establishment on repellent soils. Crops grown on repellent soils can suffer from patchy establishment, delayed emergence, low competitiveness with weeds and poor nutrient uptake.

A seed-coating technique for the water-absorbing polymer has been developed. It is hypothesised the polymer will draw water to the seed via soil humidity to aid germination and seedling survival on water repellent soils.

A surfactant coating, sourced from the Botanic Gardens and Parks Authority (BGPA) and UWA, has been used to help replant native flora after bushfires on water-repellent soils. When it rains, the surfactant leaches off to create a wetter and more favourable soil environment around the germinating seed.

Experimental evaluation of the seed coatings is assessing the impact on plant germination rates under a range of soil water conditions in glasshouse studies and evaluation of the yield benefits in the field. In these experiments, seed coating allows very low rates of the surfactant to be used.

The project is also studying the efficacy of an elemental sulphur coating on monoammonium phosphate (MAP) and diammonium phosphate (DAP) fertilisers to increase the sulphur content of these fertilisers.

Sulphur deficiency is a constraint to crop production across the grainbelt, due to sulphur deficient soils, the use of low sulphur fertilisers and sulphur leaching during high rainfall events from May to July.

The sulphur content of fertiliser can be increased by coating fertiliser granules with elemental sulphur. Elemental sulphur has the advantage over other sulphur sources because it can act as a slow-release fertiliser without affecting the efficacy of other fertiliser elements. When the elemental sulphur is coated onto fertiliser granules it has minimal impact on the influence of the N and phosphorus contents of these fertilisers.

We are testing MAP that contains 10, 15 and 20% of coated elemental sulphur in this research. This approach will reduce fertiliser handling costs while increasing sulphur fertiliser application, reducing the risk of deficiency.

To enable this research, DAFWA has purchased a seed-coating machine from Canada, which has the capacity to coat up to 2kg of seed or fertiliser. This machine is available to other parties to build the capacity of the grains industry to test other seed and fertiliser coatings.

Funding and collaborators

GRDC, DRD Royalties for Regions, BGPA, UWA

HIGHLIGHTS

- DAFWA is evaluating two seed-coating substances — a commercial water-absorbing polymer and a soil surfactant to improve crop establishment on water-repellent soils.
- Elemental sulphur-coated fertiliser granules may provide an efficient approach for overcoming sulphur deficiency.

Science team

Dr Geoff Anderson (Project leader), Christian Valentine

Right: DAFWA is evaluating the use of seed coating to mitigate the impact of water repellent soils and fertiliser coating to overcome crop sulphur deficiency.

 DAFWA Research Officer Dr Steve Davies preparing the soil face to determine the incorporation of topsoil from tillage treatments.

Green light for blue soil

Growers adopt inversion tillage to renovate problem soils, and usually to correct one or more constraints such as water repellence or herbicide resistant weeds.

The use of inversion tillage equipment (mouldboard ploughs, rotary spaders, offset discs and disc ploughs) to correct water-repellent soils and reduce high weed burdens is relatively well understood. But less is known about how this equipment mixes soils.

Soil mixing is an important factor that determines how ameliorants such as lime and clay are distributed through the soil. A better understanding of soil mixing will improve our capacity to treat more than one soil constraint at a time.

We have designed a new method for quantifying soil mixing in field experiments. To identify soil fragments, we placed green or blue-coloured soil in narrow trenches in field plots and then passed different tillage implements through the coloured soil.

Soil pits were excavated near the trenches and the pit face was advanced in 5 cm increments so we could photograph the redistribution of the soil. We then used digital image analysis to create a 3-D reconstruction of the soil profile.

Our experiments showed that the mouldboard plough, rotary spader, offset discs and disc plough fragmented the soil in a similar way, despite having different mechanical actions. We also measured the redistribution of soil from different depths, giving us a better capacity to predict how inversion tillage will modify a stratified soil.

We are working on the data with soil scientists at the UniSA, who are developing computer models of the movement of soil particles by tillage.

Our future work on soil mixing will focus on a rapid method for excavating, imaging and visualising coloured soil used as a tracer in tillage experiments.

This work is in collaboration with the Royalties for Regions project, 'New approaches to quantifying the properties of gravel soils and for sampling inverted soils to improve crop management'.

HIGHLIGHTS

- Soil mixing during inversion tillage is an important factor that determines how ameliorants, such as lime and clay, are distributed through the soil.
- We found a rotary spader, mouldboard plough, offset discs and disc plough fragment the soil in a similar way, despite having different mechanical actions.
- Our capacity to renovate a soil by creating a better soil profile is improved because we can better predict how inversion tillage will modify a stratified soil.

Science team

Dr Steve Davies (Project leader), Dr Craig Scanlan, Dr Gavin Sarre, Damien Priest

Funding and collaborators

GRDC, UniSA, UWA

DAFWA Research Officer Dr Craig Scanlan discusses pH and phosphorus nutrition with growers at a field day.

Soil pH link to phosphorus availability

DAFWA field research is providing critical evidence on how soil pH affects the response of grain yield to fertiliser.

Soil pH affects chemical properties of the soil. It can change the availability of nutrients to plants, particularly phosphorus, and also changes the level of soluble aluminium in the soil.

As pH falls below 4.5 (acidic), soluble aluminium increases to levels that are toxic to roots and reduces their growth rate, which leads to reduced access to soil water and nutrients and, as a consequence, reduced grain yield.

The relationship between soil pH, soluble aluminium and root growth is particularly important for phosphorus nutrition of crops because phosphorus is relatively immobile in soils, and toxic levels of soluble aluminium reduce the capacity of crops to access soil phosphorus.

Increasing soil pH increases the availability of soil phosphorus and can decrease the amount of phosphorus fertiliser required to maximise yield or profit.

The effect of soil pH on phosphorus availability is a critical factor for making decisions about fertiliser and lime for most WA grain producers.

Recent surveys have shown that 70% of soils used for crop production have soil phosphorus levels that are near adequate or above for maximum growth rate. However, about 70% of soils have a soil pH less than the recommended level of 5.5 at 0–10 cm depth and about 50% of soils have a subsurface pH <4.8. The negative effect on soil pH on phosphorus availability poses a risk to profit for WA grain growers.

A synthesis of our field research so far shows that soil pH is a more important factor for predicting the level of soil phosphorus supply to wheat and barley than soil phosphorus level alone.

Our field research is ongoing and will be used to provide guidelines for decision making for grain growers and advisers.

Our future work will focus on the impact of soil pH on the long-term availability of phosphorus and potassium fertilisers, which will provide evidence for quantifying their long-term economic benefit.

HIGHLIGHTS

- Toxic levels of soil aluminium occur at low pH, which restricts the capacity of crop roots to access soil phosphorus and soil water.
- About 70% of soils have a soil pH less than the recommended level of 5.5 at 0–10 cm depth and about 50% of soils have a subsurface pH <4.8.
- A synthesis of our field research so far shows that soil pH is a more important factor for predicting the level of soil phosphorus supply to wheat and barley than soil phosphorus level alone.

Science team

Dr Craig Scanlan (Project leader), Dr Ross Brennan, Dr Gavin Sarre

Funding

GRDC

GRDC soil constraints committee and local West Midlands growers discuss the large biomass responses from deeper ripping and topsoil slotting with Dr Paul Blackwell (in hole) at the trial site on deep sand in West Moora.

Deep ripping cure for soil compaction

Modern industrial-scale grain growing needs machinery that works large areas and carries as much as possible. Unfortunately, this means axle loads of 10 tonne or more — and that's like the machines we use to make roads. Such hardpan or road base produced by heavy machinery can seriously restrict crop water supply, nutrition and profit.

Thirty years ago, deep ripping to 300 mm was sufficient to bust out the hardpan, but now compaction can be deeper than 500 mm. So the GRDC-funded DAFWA Soil compaction project has built an experimental ripper to do just that.

The design also had topsoil inclusion plates on the rear tines when topsoil and top-dressed soil ameliorants, such as lime or gypsum, needed to be added into the deep ripped soil. Growers and researchers could also see the movement of the soil around the tines and plates from an observation platform built on the ripper.

Soil scientist Dr Paul Blackwell supervised the ripper construction and use on farms between Esperance in the south-east and Binnu in the northern grainbelt. This established seven farm-scale trials before seeding in 2015 on soils including deep sands, sands over clay and clays – all with hardpans and often associated with subsoil acidity, sodicity or salinity constraints to crop growth.

The research has demonstrated wheat yield improvements up to 2 t/ha and investment benefits up to $16 for each dollar invested from deep ripping. Interest has spread rapidly and growers have quickly adopted new management by increasing their ripping depth and fitting inclusion plates.

Future plans of the project will follow the progress and longevity of the treatments and further ideas to preserve the benefits of deeper deep ripping with effective incorporation of soil ameliorants.

HIGHLIGHTS

- Deeper ripping to about 500 mm made a large yield and profit increase on deep sands and deep sandy duplex soils.
- Topsoil inclusion provided a very low cost method of getting topsoil organic matter, lime, gypsum or chicken manure into the subsoil.
- The added benefit of the topsoil and ameliorants was very profitable on some sites.
- The encouraging results were rapidly distributed on twitter, enabling rapid use of deeper ripping and topsoil inclusion on grain farms in WA.

Science team

Wayne Parker (Project leader), Dr Paul Blackwell (Retired), Bindi Isbister, Glen Riethmuller

Funding
GRDC

On the right track

Industrial-scale grain-growing machinery can run over almost half the area of cropping paddocks each season.

Axle loads of 10 tonnes or more can compact the soil deeply (often to 500 mm), restricting crop water supply, nutrition and profit. Agricultural soils simply cannot support heavy loads as well as grow crops to their yield potential.

Controlled traffic farming (CTF) systems provide a solution to this conundrum by limiting compaction zones to permanent wheel tracks. This practice keeps heavy wheels off most of the paddock allowing crops to grow well, increasing yield and quarantining about 10–15% of the paddock to ‘internal roads’ or tramlines to principally support the weight of the heavy cropping gear. Other benefits include better in-crop access, improved grain quality, and less fuel and fertiliser use.

The DAFWA Soil compaction project promoted the adoption of CTF in 2015–16, following previous industry and federally funded research activities.

The transition to CTF from current traffic systems involves the whole farming enterprise accepting a plan to change from the current machinery set to one that matches the operating and wheel track width of all cropping machinery, for example a 12 m seeder, 36 m sprayer and 12 m header. This may take anything from a few years to more than 10, according to the unique circumstances of each farm.

Traffic control is especially important when farms have invested significantly in deep soil modifications (e.g. deeper ripping, incorporation of ameliorants, inversion ploughing, claying) because 80% of compaction occurs in the first pass of heavy machinery. CTF enables minimum recompaction of the soil and more opportunity to harvest further benefits from the investment in deep soil improvement.

Grower-oriented workshops used the Wheel trak calculator, a decision support tool developed by Precision Agriculture Pty Ltd with the assistance of DAFWA, the GRDC and other partners to help growers and consultants start planning a CTF system. The calculator helps individual farms estimate the percentage of the paddock that is wheeled from different combinations of cropping equipment so they can explore different machinery matching options to manage compaction.

The project will continue to provide support to growers and consultants across WA to develop controlled traffic farming systems by delivering the latest research information on compaction management through workshops, field days, social media and linking growers across the state and nationally.

An updated version of the Wheeltrak calculator, the Compaction calculator, will be released in 2017 with additional capacity to be added throughout the remainder of the project.

Funding and collaborators

GRDC, Precision Agriculture, DAF Qld

HIGHLIGHTS

- Grower-oriented workshops helped farm managers make customised plans for transitioning machinery and leading the business into controlled traffic farming (CTF).
- Workshops ran at Geraldton, Bencubbin and Esperance in 2015 and in Dalwallinu and Moora in 2016, helping up to 77 growers and consultants.
- The workshops were designed as a package with the help of experienced extension specialists to enable any group of consultants to use them.
- Decision support tools have been successfully developed and used to assist growers and consultants evaluate different scenarios for matching machinery.

Science team

Wayne Parker (Project leader), Dr Paul Blackwell (Retired), Bindi Isbister, Dr Stephen Davies, Glen Riethmuller, Glenn MacDonald, Jeremy Lemon, David Hall

Right: DAFWA Development Officer Bindi Isbister.

Meeting the many needs for soil acidity to be managed effectively

Vast areas of southern WA suffer from acidic soils – to the value of over $1 billion in lost productivity annually. So much so, that the majority of growers now place the management of soil acidity in their top three management priorities.

Managing soil acidity is both achievable and profitable.

Liming – quite simply the application of lime – has been found to be the most effective strategy to restore the overall health of acidic soil. However, there are three conditions. The lime must be used in the right quantity in the right place (in the paddock) and down the soil profile.

DAFWA works closely with Lime WA Inc. whose members follow a voluntary code of practice. Lime WA members provide lime quality information for growers that we audit independently. To determine trends, members have provided total sales data for 2004–16, representing an estimated 80% of market share.

Lime use increased considerable after 2013, following the completion of two effective projects that targeted soil sampling and provision of information. It is this change that current projects aim to support and build on.

A key output is to provide information that growers need in a simple and accessible way. We are working on a revised lime/acidity calculator, which will assist growers to make decisions and fill a knowledge gap related to acidification rates.

We understand that the annual acidification rate (the amount of 'lime' growing a crop uses) is poorly understood.

We continue to support the effective management of soil acidity by growers through:

- developing an easy lime/acidity calculator that focuses on increasing growers' knowledge and understanding of acidification rates associated with farming practices
- focusing on an integrated approach to soil management to maximise and preserve additional benefits through collaboration with all soils projects
- providing information and support to other departments, projects and groups.

Funding and collaborators

GRDC, Lime WA Inc., Rural Solutions SA, Central West Farming Systems (NSW), Southern Farming Systems (Vic), Desiree Futures

HIGHLIGHTS

- The use of agricultural lime has remained high and, while not yet at the desired level to address existing and ongoing acidity statewide, there are good signs that specific regions are making progress.
- A new Royalties for Region-funded 'Watering Western Australia' project through the Department of Water will provide valuable information to further support growers and measure changes in soil condition.
- We will conduct a 'third time of sampling' following the gains made in previous projects (2006–2013), which developed soil pH risk maps.
- Over the past 12 months, we have assisted three significant external studies:
  - » 'Lime transport routes', with the Grainbelt Development Commission.
  - » 'Lime Situation Report 2015', prepared for South Coast Natural Resource Management by Julia Fry.
  - » 'Evidence for the economic impacts of investment in National Landcare Programme activities', Department of Environment, Canberra.

Science team

Chris Gazey (Project leader)

Above: DAFWA Research Officer Chris Gazey sprays universal pH indicator onto the soil profile.

Below: DAFWA Research Officer Chris Gazey speaking to growers from a soil pit at a field day.

Getting lime in deeper and quicker to recover acidic soils

Liming is an effective ameliorant for soil acidity (low pH) which occurs in much of southern WA.

Our soil acidity group is developing ways to maximise the benefits of applying lime to help growers (particularly in the eastern WA grainbelt) to manage subsurface acidity more cost effectively.

DAFWA and UWA researchers are looking at key areas to increase the returns to growers from managing soil acidity:

- boosting the benefits from conventional liming using limesand, limestone or dolomite. In particular, we aim to develop and assess incorporation techniques for old (applied in the past few years) and newly applied lime
- assessing the potential for common alternative lime sources, such as liquid limes or other granulated or prilled products.

We have identified field trial sites for 2017 and also paddocks where growers have carried out some level of soil disturbance. We will use these sites to assess the effectiveness of incorporation using varied techniques.

With Rural Solutions South Australia, we will establish a site on the Eyre Peninsula in recognition that susceptible soil types in SA are also at risk of increased acidity. The aim will be to help growers avoid the development of the situation that much of WA now faces.

As the project progresses, we will work closely with the other soils projects, particularly those in the Soils Constraints – West group, to develop an economic framework that will allow growers to make informed decisions about integrated management of multiple soil constraints.

In addition, we will continue to assess a range of liming products in laboratory and glasshouse experiments for their capacity to neutralise soil acidity, using the results to guide experimental treatments in the field in the future.

Funding and collaborators

GRDC, UWA, Rural Solutions South Australia

HIGHLIGHTS

- We have established a long-term field experiment at Merredin to examine the capacity for N fertiliser strategies to decrease acidification rates.
- Soils Constraints – West projects and growers have recently shown that significant incorporation of limed topsoil is possible behind deep ripping points with plates designed to hold the soil open for longer. Understanding the soil and lime behaviour will be a focus of further work.
- An economic framework to assess management strategies for multiple soil constraints is being developed under the Soil Constraints – West project ‘Sub-soil constraints – understanding and management’. Our research will contribute to this framework.

Science team

Chris Gazey (Project leader), Dr Gaus Azam, Daron Malinowski, Dr Craig Scanlan

Right: DAFWA Research Officer Dr Gaus Azam inspecting root growth in a limed and deep ripped soil.

DAFWA Research Officer David Hall with growers at a field day.

Know your enemy: subsoil constraints

Subsoil constraints cost WA grain growers more than $1 billion per annum in lost production (Petersen 2016).

The constraints that limit plant growth include nutrient disorders (toxicity, deficiency), compaction, acidity, sodicity and transient salinity. These constraints restrict root depth and function to the extent that water and nutrients can't sustain production at or near the rainfall limited yield potential.

Efficient use of rainfall is important to make the most of reduced rainfall and associated climatic effects in the grainbelt. Often growers lack sufficient diagnostics to confidently identify and manage these subsoil constraints.

This project is designed to increase profitability through improved diagnostics and management options.

A combination of glasshouse and field experiments has been established to characterise crop yield responses to subsoil constraints. Experiments are being conducted on acidic sandy soils through to alkaline clay soils from Dalwallinu to Esperance.

Our research is focusing on deeper tillage and amendments (fertiliser, organic materials, gypsum, lime) to improve root growth, soil water storage and crop yields.

A key outcome of this project is to refine tools to identify subsoil constraints and their impacts on crop production. These tools range from assessment of the relationship between plants and soil through to economic models that can help growers set priorities for management options to reduce subsoil constraints.

HIGHLIGHTS

- The online tool, MySoil, has been developed to provide detailed soil information and management options for differing soil types and climatic zones in the grainbelt.
- Costs of subsoil constraints have been calculated that enable industry and government to make informed decisions on future needs and funding.
- An experimental program has been established with 15 sites from Dalwallinu to Esperance. Significant production benefits have been recorded as a result of improved access to water and nutrients.
- Extension activities in two years have reached more than 550 growers, 200 scientists and 170 industry consultants.

Science team

David Hall (Project Leader), Dr Shahab Pathan, Caroline Peek, Grey Poulish, Dr Geoff Anderson, Jeremy Lemon, Chris Gazey, David Dodge, Glen Riethmuller, Dr Stephen Davies, Grant Stainer, Glenn McDonald, Wayne Parker, Dr Ed Barrett-Lennard, Dr Karen Holmes, Dennis van Gool, Ted Griffin, Dr Liz Petersen

Funding and collaborators

CSIRO, Precision Agronomics Australia, Fitzgerald Biosphere, West Midlands Group, Liebe Group

Tech innovations improve soil information

Agricultural land management is becoming inherently spatial. Growers and consultants recognise that improved spatial information will help to diagnose and manage soil constraints. Current state soil maps are not at a resolution that will allow growers to plan and implement remediation activities at farm or paddock scales. Advances in farm equipment, land imaging technology and personal computing present the opportunity to develop higher-resolution soil information for use by growers. Such information is in demand for variable management, including management of subsoil constraints (nutrient disorders, compaction, acidity, sodicity, transient salinity).

A sub-component of the DAFWA research project Overcoming subsoil constraints supports agronomic research, extension, and economic analysis in the grainbelt by identifying:

- where subsoil constraints are most likely to be limiting production
- how much land is affected
- where constraint amelioration is most likely to be successful.

Historical soil sample data and survey maps were combined to identify subsoil constraints, model their occurrence and severity and then map their likely distribution.

Further research combines remote sensing images (satellite, airborne, vehicle-towed) with traditional soil maps and local knowledge to improve the spatial detail of subsoil constraint maps, with the goal of improving farm-level soil information.

Areas have been defined for detailed investigation around Geraldton, Merredin, Katanning, and Esperance, where remote-sensing datasets of varying spatial resolution will be compared and integrated to test map improvement.

Key outcomes of this work will include improved maps of subsoil constraints and geographically relevant soil information in the grainbelt, as well as improved online access to maps and information developed by DAFWA for use by agricultural professionals and others.

Future work will assess whether new methods of incorporating available remote sensing imagery (satellite, airborne, vehicle-towed sensors) with traditional soil maps can improve spatial detail for on-farm soil constraint maps; to publish research results and develop extension materials to connect agricultural professionals and growers with relevant spatial soil information and tools.

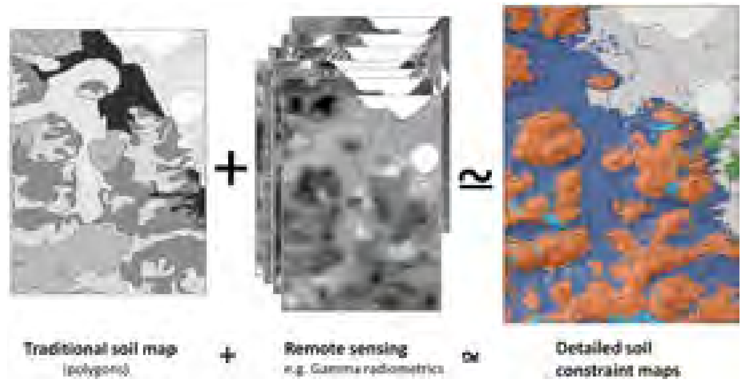


Figure 1. Illustration of combining traditional soil maps with remote sensing imagery to make alternative, higher spatial resolution maps of soil information.

Funding and collaborators

GRDC, CSIRO and Precision Agronomics

HIGHLIGHTS

- Eighteen subsoil constraints to wheat production have been modelled by soil type and region, and mapped over the grainbelt to visualise their variable extent. Area calculations from these maps enable analysis of the relative costs of different subsoil constraints to agricultural production.
- Grainbelt areas with multiple constraints were identified to help prioritise land with a higher likelihood of response to management.

Science team

Dr Karen Holmes (Project leader) Dennis van Gool, Ted Griffin, Justin Laycock

Right: DAFWA Research Officer Dr Karen Holmes and Ted Griffen.

Breaking out of the box: managing sodic soils

What kind of problems would we expect to see if we grew cereals in soil contained in a shallow box with an impermeable bottom? In essence, the soil would have a limited water-holding capacity, and fertiliser and salt would accumulate in the soil over time.

This is exactly the problem that is faced by grain growers on millions of hectares of land affected by sodicity (excess sodium) and alkalinity (soil pH values ~8.5) in WA. Both stressors cause the dispersion of subsoil clays, which creates an impermeable barrier to the penetration of water, fertiliser and salt below depths of about 50 cm in the profile.

For many of these soils, it is too expensive to ‘break the bottom out of the box’, which would require combinations of deep ripping and the application of gypsum and acid to the subsoil. Different solutions are therefore required.

Mitigation also requires genetic tolerance to a wide range of traits. These genes are available in diverse wheat germplasm but require identification and pyramiding.

Researchers at DAFWA are focusing on two approaches to increase crop production from affected areas.

- First, in collaboration with a national team (University of Adelaide, University of Queensland, NSWPI, DEDJTR Victoria), we are selecting wheat genotypes that are better adapted to these soils. Trials to screen wheat varieties and populations for tolerance to sodic/magnesic dispersive soils in WA have been conducted in 2015 and 2016 at Merredin and Broomehill.
- Second, in collaboration with researchers from CSIRO and University of New South Wales, we are using water harvesting techniques to better manage the limited water resources within the ‘shallow box’ to grow more effective crops. Proof-of-concept trials to improve the harvesting of surface water are being conducted at sites near Merredin, Bonnie Rock and Kalannie.

Field trials will continue for the next two years. We expect that the results of the NVT analysis will be published in 2016/17. Pre-breeding work will continue until 2020 and will involve crossing work and screening segregating populations.

Funding and collaborators

GRDC, UA, UQ, DPI, DEDJTR, DELWP, CSIRO, UNSW

HIGHLIGHTS

- We are evaluating national and international germplasm to combine traits into useful breeding lines.
- Analyses of two large-scale WA soil databases show that soil sodicity and high soil alkalinity (pH values >8) cause soil dispersion and therefore the accumulation of salt (from rain) in the soil profile.
- We have compiled a database of more than 600 National Variety Trials conducted over southern Australia (WA, SA and Vic.) since 2008. This also shows that transient salinity is caused by sodicity and soil alkalinity, and that transient salinity impacts most severely on the growth of our major wheat varieties under conditions of <200 mm of seasonal (April to October) rainfall.
- Trials have been planted at two locations in WA to determine the benefits of water harvesting techniques to overcome the impacts of transient salinity and soil dispersion on crop growth.

Science team

Dr Darshan Sharma and Dr Ed Barrett-Lennard (Project leaders), Rosemary Smith, Caroline Peek, Dana Mulvany, Shahajahan Miyan, Glen Riethmuller, Meir Altman

Right: DAFWA Research Officer Dana Mulvany and Development Officer Caroline Peek measuring soil properties at a sodic soil experimental site.

Micronutrients are essential for crop production

The interest in micronutrients fertiliser for crop production has been due to the increased use of one-pass seeding equipment. Copper (Cu) and zinc (Zn) are immobile in soils, availability and uptake by plant roots depends upon roots growing to the particle of micronutrient in the soil. Traditionally cultivation has distributed the micronutrients through the soil and increased the likelihood of root interception Cu and Zn particles. In no-till systems, there is limited physical distribution of micronutrient fertiliser particles.

The maintenance strategy, where small amounts of micronutrients are applied each year, has gained popularity in recent years. The application of small amounts in compound fertiliser in cropping can be used to distribute Cu and Zn through soil. The maintenance strategy works provided micronutrient levels in the soil are already adequate. If the maintenance strategy works it will be because Cu and Zn are applied in different positions each year and distributed through the soil to some extent by subsequent sowings.

Availability of micronutrients and effectiveness of fertilisers depend on many seasonal and environmental conditions. However, the pH of soil is an important factor affecting the availability of Zn, Cu, manganese (Mn) and molybdenum (Mo).

As soil pH increases, Zn, Cu and Mn are more strongly fixed by soil constituents (e.g. clay) and hence the availability to plants declines. However, Mo availability to plants increases as the soil pH increases. Acidic soils, with soil pH values below about 4.7 are frequently Mo deficient for cereal production. A liming program to increase soil pH decreases the need for frequent applications of Mo fertiliser in cropping systems. The field research is ongoing and will be used to provide guidelines for decision making on micronutrients for grain growers and advisors.

This project will produce clear guidelines for management of micronutrient disorders for mainly wheat in WA. The guidelines will be based on data that has been objectively tested for its relevance to modern cropping systems for current technologies and economic circumstances.

Funding and collaborators

SARDI, MU, CSBP, DPI

HIGHLIGHTS

- There is increasing concern that the packages developed for micronutrient fertiliser advice may not be adequate for current cropping systems, or for new areas of cropping that are quite different to the areas where the recommendations were originally developed.
- There is also increasing concern that micronutrient supplies from the soil may no longer be adequate for cropping systems that are more productive, more intensive and more reliant on supplies of fertiliser N and P.
- Mo deficiency now appears on soils that have acidified. Approximately 12% of soils have a soil pH less 4.5 (0 to 10 cm depth) and low extractable Al where large responses to Mo fertilisers for crop production have been measured.

Science team

Dr Ross Brennan (Project leader), Paul Matson,
Dr Craig Scanlan

Right: Research plots at Wongan Hills.

Soil sampling for assessment of crown rot levels in crop rotation trials.

Crop protection portfolio

Crop weeds, invertebrate pests and diseases cost WA grain growers millions of dollars a year in control strategies and lost production. Annual losses to the Australian grains industry due to disease were estimated to be over $1.3 billion per annum in 2009 with potential losses of over $4 billion. Associated costs for invertebrate pests were estimated to be over $350 million in 2013. The current (2016) estimated annual cost of weeds to Australian grain growers is $3.3 billion.

In 2015/16, $7.7 million was invested in R&D through the crop protection portfolio by engaging 51 staff on 26 projects across all cropping regions. These projects recommend management strategies to minimise the impact of pests on crop yields and reduce the potential downgrading of grain due to damage or contamination.

Together, the projects examine the biology of individual species, develop management recommendations and integrated management packages, decision support tools and new techniques to enable grain growers to quickly and effectively manage these pests.

Crop pathology R&D concentrates on foliar and root diseases caused by fungi, viruses and nematodes, including sclerotinia and blackleg (canola), powdery mildew and rust (wheat and barley), crown rot and rhizoctonia, bean yellow mosaic virus (pulses) and root-lesion nematodes. There is also a focus on quantitative epidemiology, crop disease modelling and risk forecasting, in addition to evaluating crop varietal responses to disease enabling growers to make informed crop management decisions.

Invertebrate pest R&D addresses aphids, red-legged earth mites, slugs and snails. We also investigate the use of beneficial species and how they can be used to keep pest populations below damaging levels.

With a shifting climate and a change in farming systems, the challenge of controlling herbicide resistant and emerging weeds such as fleabane and brome grass is examined in several weed projects.

Spray application technology and pesticide delivery to minimise the risk of pesticide spray drift while optimising canopy coverage and penetration and the herbicide tolerance of new crops is also being investigated.

Current populations and distribution of each pest (including insects, crop diseases and weeds) and their associated pesticide resistance are captured through our research projects as well as through the WA grower and industry network via Pestfax Reporter and PestFax Map.

Useful and timely information is delivered to our clients through regular electronic newsletters such as PestFax, web-based disease risk forecasts, an SMS alert service, grains research update presentations, webpages, webinars, YouTube video and other media. Many of our field trials are located on Grower Group Field Day sites, allowing staff to directly showcase their research to consultants and growers. Annual training courses on integrated disease and insect pest management and identification are available to industry.

Dr Sally Peltzer
Portfolio Manager

Crop disease protection: Are we prepared?

DAFWA researchers are helping to protect crops from disease by using the latest techniques to gain a better understanding of disease function. Communicating the results is equally important.

Through a new GRDC-supported project, we are developing management strategies to help growers reduce their losses due to crop disease.

The project focuses on research and extension in managing fungal and viral diseases in cereals and pulses in the western region.

Through the Centre for Crop and Disease Management (CCDM) at Curtin University, the project maintains close links to research in rapid molecular detection and improved detection and management of fungicide-resistant pathogens.

DAFWA staff carry out field trials to understand the biology of crop diseases and to investigate yield impacts.

Targeted diseases include yellow spot, stagonospora nodorum, leaf rust and powdery mildew in wheat; loose smut, spot-type net blotch, net-type net blotch, powdery mildew and leaf rust in barley; septoria in oats; and sclerotinia and anthracnose in lupin.

Surveillance activities include:

- sampling and testing to monitor pathogen populations
- checking the distribution and importance of new diseases (for example, white grain disorder)
- trialling new methodologies for quantifying the severity of disease in paddocks
- using spore trapping networks to provide early warning.

Surveillance activities over the past three years have helped identify three new leaf rust pathotypes (two in wheat and one in barley). In 2015, staff submitted three of the four samples of a new wheat leaf rust pathotype to Sydney University.

Extension, communication and training are a priority, with timely delivery of crop protection information through a range of formats contributing to the success of the project. Field days, seminars, online articles and videos, workshops and notifications through Pestfax are all vital channels.

Science team

Geoff Thomas (Project leader), Ciara Beard, Dr Kithsiri Jayasena, Andrea Hills, Dr Daniel Huberli, Dr Ravjit Khangura, Andrew van Burgel, Dominie Wright, Anne Smith, Lucy Debrincat, Jason Bradley, Mirjana Banovic, Laurie Wahlsten

Funding and collaborators

GRDC, Curtin University (CCDM), Thinkspatial

HIGHLIGHTS

- The project took prompt action in response to the 2015 outbreak of wheat powdery mildew and released historical data to improve understanding of the disease and growers' capacity to manage outbreaks, set up in-paddock trials to investigate the impact and management of powdery mildew, and circulated the results for improved decision making in the new season.
- A series of timely crop protection webinars and six YouTube videos were produced in response to disease issues (wheat powdery mildew, barley leaf rust, wheat streak mosaic virus). The videos attracted more than 600 views, including over 200 views of the highly topical wheat mildew video in the 2015 growing season.
- With spatial information specialists, Thinkspatial, we collected images for study of rhizoctonia bare patch in cereal paddocks using UAVs (unmanned aerial vehicles).
- A two-day annual workshop is run to train commercial agronomists, agrichemical and agribusiness staff in how to identify diseases.

Above: DAFWA Research Officers Andrea Hills, Dr Daniel Huberli and Geoff Thomas with Rain Liu using UAV's (unmanned aerial vehicles) to collect images to study of rhizoctonia bare patch in cereal paddocks.

Below: DAFWA Research Officer Geoff Thomas looking at disease trials at South Perth.

Using foliar fungicides to prevent wheat powdery mildew

In 2015 powdery mildew was a widespread and ongoing issue in wheat crops in the northern and central grainbelt and in areas around Esperance. DAFWA plant pathologists generated important new data and led industry collaboration to better manage powdery mildew in wheat.

The disease hadn't been seen at such widespread or severe levels in WA since the late 1990s or early 2000s so there was a great need for information on control strategies to be developed and disseminated for industry.

Field trials were established in growers' paddocks in response to a widespread outbreak of the disease, which appears as fluffy white growth on wheat leaves. Most common varieties, such as Wyalkatchem, Mace and Corack, were susceptible.

No yield loss data had been gathered since the late 1990s so industry was not familiar with the damage powdery mildew could do to current varieties and how it would be best controlled. Available historical data was collated by DAFWA and disseminated to industry to help guide in-crop management decisions in 2015.

In field trials, DAFWA's plant pathology team were able to compare which fungicide products and application timings minimised wheat yield losses and grain quality defects when disease struck mid-season.

The trials determined that well-timed foliar fungicides could provide significant protection from powdery mildew, providing an average yield response of 10% across all trials. This outcome supported the results of historical trials and provided guidance for management decisions in the coming season.

To help guide growers and agronomists through in-season decision making, DAFWA extended historical trial and epidemiological data through traditional platforms such as the PestFax newsletter and print media outlets, and trialled newer platforms such as webinars and YouTube videos.

The collaboration, led by DAFWA, allowed the formation of a big picture view of strategies to be used by agronomists and growers in 2016 and will be relied on for years to come to reduce financial losses to this disease. It also raised DAFWA's profile as an industry leader, valued for bringing together the research of various groups for the benefit of all in the grains industry.

Management research continues to investigate options for disease control early in the season by comparing fungicides applied at seeding (seed dressings and in-furrow on fertiliser) with a foliar fungicide applied at early stem extension stage.

Funding and collaborators

GRDC, Landmark, Imtrade, Liebe Group, Northampton Agriservices

HIGHLIGHTS

- We responded rapidly by establishing four field trials from Geraldton to Esperance to gather data on yield and quality loss and compare fungicide products and timing.
- DAFWA compiled results from these trials and the trials of industry partners to update recommendations for disease management to be used by growers and agronomists to minimise losses to this disease.

Science team

Ciara Beard (Project leader), Geoff Thomas, Andrea Hills, Anne Smith, Jason Bradley

Above: DAFWA Research Officer Ciara Beard in a wheat crop infected with powdery mildew.

Putting up resistance to rust

Leaf rust caused by *Puccinia hordei* is a significant disease of barley in WA. It is an aggressive and difficult foliar disease to control and can be a recurring problem in crops in the southern high rainfall zones.

Infection leads to the production of pustules that give the appearance of 'rust' on the leaves. The pustules are small and circular, producing a mass of orange-brown spores predominantly on the upper leaf surfaces. As the crop matures, the pustules turn dark and produce black spores embedded in the old plant tissues and stems.

Barley leaf rust can reduce grain yield by over 30% in severe infections. A GRDC-funded research project focuses on steps to prevent its spread.

The project encourages barley growers to use all the tools available for rust management including:

- removing the green bridge (volunteer cereals)
- growing varieties with adequate resistance to leaf rust
- applying fungicides to seed for early season rust suppression
- monitoring crops for rust and if needed, applying foliar fungicides for disease control.

Continued monitoring of all rust pathotypes will help identify and respond to changes in the virulence of rust. Aerial spore trapping of rust is being investigated for regional early warning and work continues on identifying the optimum times to apply fungicide to fight barley leaf rust.

Funding and collaborators

GRDC, Tel Aviv University (Institute for Cereal Crops Improvement ICCI), University of Sydney

HIGHLIGHTS

- This project aims to manage leaf rust of barley, a recurring problem in southern high rainfall zones of Western Australia. Leaf rust can reduce grain yield by over 30% in severe infestations.
- Spore traps are used extensively to monitor airborne cereal foliar pathogens such as rusts to warn the growers in the region.
- Yield loss in barley varieties with combinations of resistance genes are tested against fungicides.
- The timing of applications of in-crop foliar fungicide in relation to rust is being addressed.

Science team

Geoff Thomas (Project leader), Dr Kithsiri Jayasena, Andrea Hills, Laurie Wahlsten, Jason Bradley

Left: Rust on barley leaf.

Right: DAFWA Research Officer Dr Kithsiri Jayasena with a spore trap to monitor airborne pathogens.

Canola crops: keeping sclerotinia and blackleg at bay

Sclerotinia stem rot is a fungal disease that attacks canola as well as over 400 broadleaf species worldwide. The complexity of the stem rot pathogen and lack of genetic resistance pose significant agronomic challenges to growers and advisers, especially in tight rotations and in medium to high rainfall areas. Losses to sclerotinia in WA alone were estimated at $59 and $23 million in 2013 and 2014, respectively.

To provide growers with the best disease management package, DAFWA's research over the past six years has focused on factors affecting disease development, product effectiveness, and the timing of fungicide applications.

Field trials have shown that effective control can be achieved by applying registered fungicide matched with the timing of sclerotinia spore release.

In 2015 the most effective and economical treatment was to apply fungicide at 25% or 50% bloom, ensuring maximum petals were covered. A well-timed single spray resulted in an increase in seed yield of 29% (compared with untreated plots), resulting in a $178/ha net return. Whereas, fungicide applied at late bloom stages were not economical (Fig. 1).

Blackleg caused by *Leptosphaeria maculans* is also an on-going issue. A major focus of research is to improve blackleg management strategies under tight canola rotations and determine the risk of breakdown of resistance.

Research indicates that blackleg is most economically controlled with seed dressing in conjunction with in-furrow fungicide application. Foliar applied fungicides have a role in in-crop disease management, particularly if targeted at early stages of crop development.

Data collected in the fungicide trials has been used to develop and validate the fungicide spray decision tool that can be accessed online at agric.wa.gov.au.

Ongoing research will focus on judging the optimum time for applying fungicide and developing integrated approaches to managing sclerotinia and blackleg profitably.

Researchers will use current and future epidemiological data to develop a decision support system that will provide early alerts of risk periods and help growers to make decisions about the use of fungicide sprays.

Funding and collaborators

GRDC, University of Melbourne, DPI, Marcroft Grains Pathology, SARDI, CSIRO

HIGHLIGHTS

- DAFWA continues to improve sclerotinia management packages for growers.
- It is most effective to spray fungicide early in the event of early epidemics rather than late. Late applications are only effective if the spores are released late in the season.
- DAFWA has developed cost-effective approaches for controlling blackleg — for instance, for maximum economic returns apply seed dressing in conjunction with in-furrow application to varieties rated moderately resistant and below.

Science team

Dr Ravjit Khangura (Project leader), Mehreteab Aberra, Stuart Vincent, Andrea Hills, Ciara Beard, Anne Smith

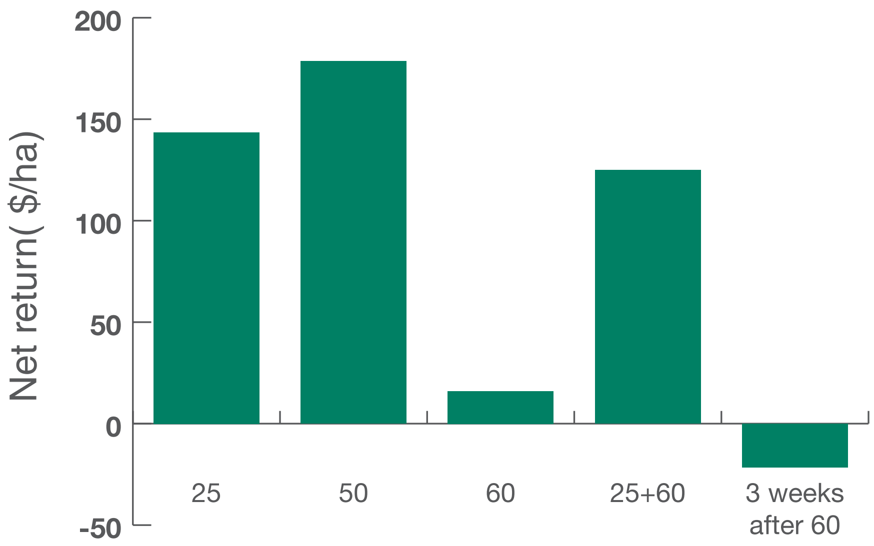


Figure 1. Net return ($/ha) from applying protectant fungicide application at different bloom stages (bloom %) of canola in a trial at South Stirlings.

Above: Sclerotinia on canola.

Left: DAFWA Research Officer Dr Ravjit Khangura.

Liquid delivery controls rhizoctonia root rot

Rhizoctonia root rot caused by the fungus *Rhizoctonia solani* AG8 occurs across the WA grainbelt and is estimated to cost the wheat and barley industry $27 million annually. A recent breakthrough has been in the use of liquid banding of fungicides to reduce the risk of rhizoctonia root rot in cereals.

Research in WA and SA has produced significant gains from liquid banding treatments. Two new in-furrow fungicides with new active ingredients, Uniform® and Evergol® Prime, were subsequently registered in 2015 with data from 10 DAFWA trials supporting the registrations. It is the first time that a chemical option to control rhizoctonia in barley and wheat has proven to consistently achieve significant yield responses.

For Uniform® trials, the banding treatments producing the most consistent results were applied as a split on the soil surface behind the press wheel and in-furrow 3 cm below the seed. For example, in wheat, at the 400 mL/ha rate, there was a 18% greater yield on average for all trials in WA and SA compared to the untreated. For barley, there was a 20% yield improvement when the fungicide was applied as a split application. A single banding of fungicide below the seed only produced 7-13% yield increases from the different rates in wheat and barley. The severity of the disease ranged from low to very high in trials conducted in paddocks with the natural rhizoctonia infections. (Figure 1)

Fungicides do not eliminate rhizoctonia and should be used as part of an integrated management program. DAFWA experiments have shown that sowing a break crop, specifically canola, or applying a chemical fallow, significantly reduces rhizoctonia inoculum in soils between successive cereal crops. Additionally, the severity and patch size of root disease from rhizoctonia were reduced in the cereal crop following canola.

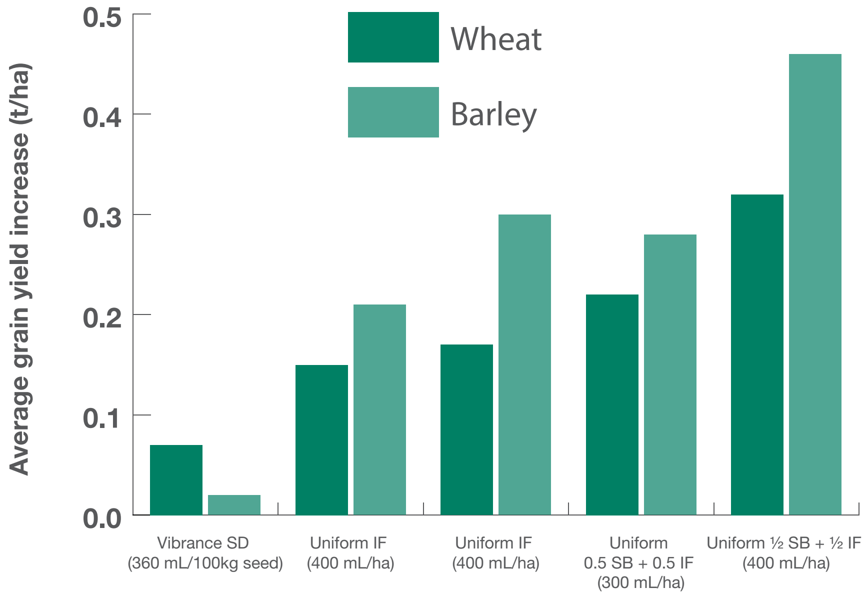


Figure 1. Grain yield increases with seed-dressing and in-furrow (IF) and surface-banded (SB) fungicides.

Funding and collaborators

GRDC, SARDI, Bayer Crop Science, Syngenta, UniSA

HIGHLIGHTS

- New fungicide packages that minimise the impact of the cereal disease rhizoctonia bare patch, resulting in significant yield responses, have been developed by research involving DAFWA, SARDI and two chemical companies.
- Data from 10 DAFWA trials was used to support the registration of the new in-furrow fungicides, Uniform® and Evergol ® Prime, and the new seed-dressing fungicides, VibranceTM and Evergol® Prime.
- Significant and consistent yield improvements of 0.3 and 0.5 t/ha were obtained in wheat and barley, respectively, with the in-furrow fungicide.
- Canola and chemical fallow can significantly reduce rhizoctonia root rot in intensive cereal cropping.

Science team

Dr Daniel Hüberli (Project leader), Miriam Connor, Kris Gajda

Right: DAFWA Research Officer Dr Daniel Hüberli next to the seeder with the capacity for fungicide liquid banding.

Left: Wheat seedlings with rhizoctonia root rot expressed as spear-tipped roots.

Yield loss to Fusarium crown rot: Is there a better choice among wheat and barley varieties?

Crown rot is primarily caused by the fungus *Fusarium pseudograminearum* and was estimated in 2009 to cost the Australian grains industry $97 million per year in wheat and barley losses.

New wheat and barley varieties have been released with improved resistance to crown rot, but there is no experimental field evidence of tolerance in WA. During 2013 – 2016 DAFWA researchers evaluated varieties in nil and inoculated paired plots to demonstrate the economic benefits of varietal selection in paddocks with high crown rot.

In the wheat trial at Wongan Hills in 2014, Emu Rock (MS to crown rot) yielded 300 kg/ha more than Mace (S to crown rot) under crown rot pressure. Under nil crown rot inoculum, Mace out-yielded Emu Rock by 200 kg/ha (Figure 1).

In the barley trial, Litmus, La Trobe and Baudin had the lowest yield reduction (Figure 2).

Therefore, it is important to understand the crown rot risk in a paddock to make the right variety choice.

All wheat and barley varieties suffer some yield loss to crown rot as there is no full resistance. A multi-target management strategy is required for paddocks with crown rot including using break crops such as canola in the following year to reduce the carry over of the disease.

It is also important to control autumn cereal weeds and volunteers to minimise the build-up of inoculum. If sowing cereal, considerations include sowing at the first window opportunity, using a registered seed treatment, sowing off the infected stubble row in soils that are not non-wetting and using a less susceptible wheat variety or sowing to barley which finish earlier.

HIGHLIGHTS

- Crown rot incidence has been found across WA's grain belt, with mainly the low to medium rainfall regions observing the white head expression at the end of the season.
- Some wheat and barley varieties have consistently yielded better under crown rot pressure in paired plots across 2 years, Emu Rock and Litmus have been the best performers.
- Effective management of crown rot needs to be multi-target approach including crop rotation, sowing early, inter-row sowing, weed control, and use of registered fungicide.

Science team

Dr Daniel Hüberli (Project leader), Miriam Connor and Kris Gajda

Funding and collaborators

GRDC, SARDI, DPI, DAF Qld, DEDJTR, DRD
Royalties for Regions

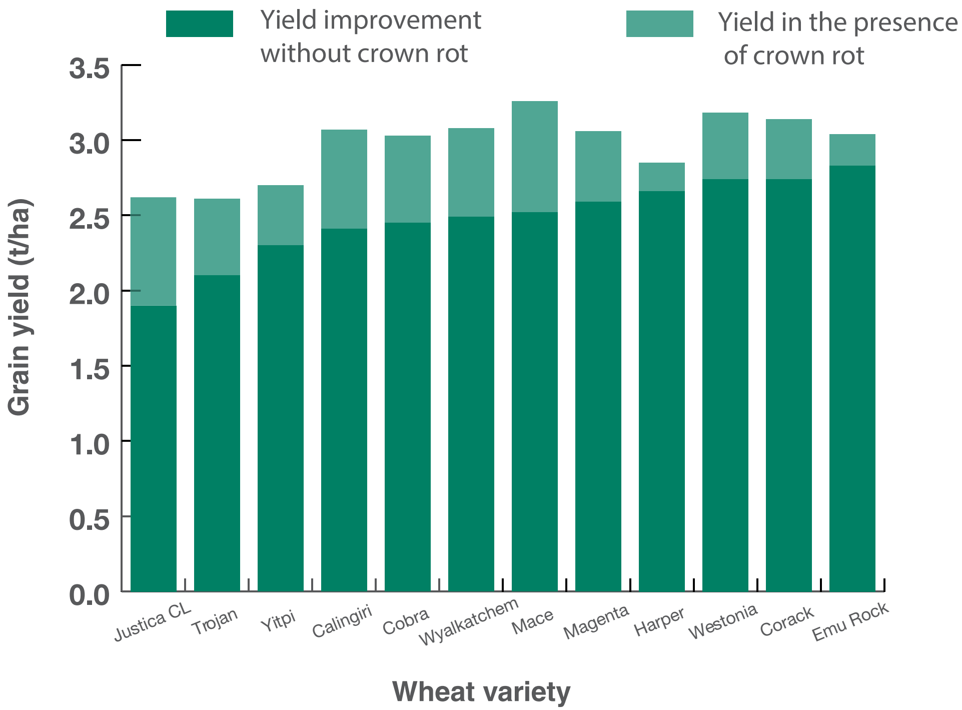


Figure 1. Grain yield for 12 wheat varieties in uninoculated and Fusarium *pseudograminearum* inoculated plots at Wongan Hills in 2014. Resistance ratings: Emu Rock (MS), Trojan (MS), Magenta (MSS), and remaining varieties (S) to crown rot.

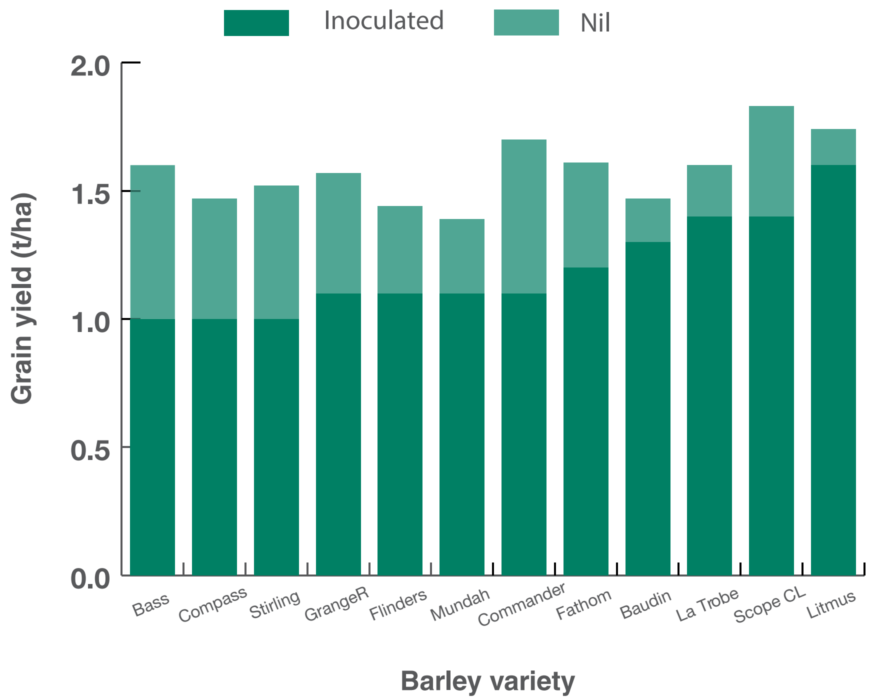


Figure 2. Grain yield for 12 barely varieties in uninoculated and Fusarium pseudograminearum inoculated plots at Wongan Hills in 2014.

Root lesion nematodes in WA

Root lesion nematodes (RLN) are microscopic worm-like animals that feed on plant roots causing yield loss in susceptible crops including wheat, barley and canola. RLN is estimated to cause yield losses in wheat and barley crops of $202 million a year in WA alone.

In 2014–15 these nematodes were found in 81% of 614 paddocks tested and at least 50% of infested paddocks had RLN at potentially yield limiting levels (>2RLN/g soil, Figure 1).

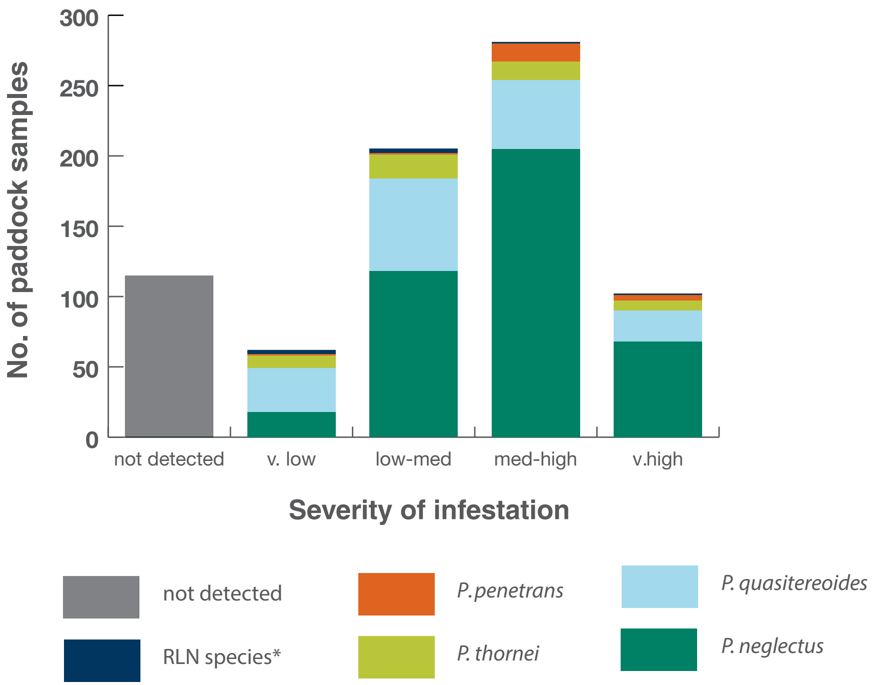


Figure 1. Number of paddocks infested with each Pratylenchus species in each severity of infestation category, 2014–15. Adapted from Pestfax database, DAFWA.

Note: Severity category, very low = 0–0.2 RLN/g soil; low = 0.2–2 RLN/g soil; medium = 2–15 RLN/g soil; and high = >15 RLN/g soil. RLN species* = RLN species undefined due to lack of adults for identification.

Pratylenchus neglectus and *P. quasitereoides* (formerly called *P. teres*) are the most common species and are found in 67% and 27% of paddocks, respectively. WA is unique with *P. quasitereoides* only causing issues in broadacre cropping.

A meta-analysis of 28 large-scale DAFWA field trials conducted over 19 years showed that RLN species *P. neglectus* and *P. quasitereoides* can cause losses of up to 17% and 19% for barley and wheat, respectively.

RLN has the ability to desiccate over dry periods, rehydrating when soil moisture becomes available. The nematodes then feed on roots of available susceptible plants and continue their life cycle.

Crop rotation, summer and autumn weed control, adequate nutrition and variety choice in susceptible crops are the best management options for reducing RLN densities in infested paddocks. Changes in seasonal conditions and increasing canola in rotations may be responsible for increasing RLN impacts in crops in recent years.

If levels are medium to high (>10 nematodes/mL of soil or >10 000 nematodes/g dry root), we recommend growing a moderately resistant or resistant crop or pasture for one to two cropping seasons to reduce nematode numbers to a level that is not yield limiting.

Funding and collaborators

GRDC, USQ, UA, DEDJTR, SARDI, NSW DPI, COGGO

DAFWA is collaborating with research partners in northern and southern Australia to further quantify the economic benefits of managing RLN populations in infested wheat and barley crops. This research will also provide baseline information for yield impacts to canola and lupins due to *P. neglectus*, *P. quasitereoides* and *P. penetrans*. Resistance of milling and hay oats to RLN is also being investigated.

Crop rotation is the key for nematode management. We need to continue developing rotational recommendations through further testing of current options, and new viable alternatives.

HIGHLIGHTS

- Four RLN species *(Pratylenchus neglectus, P. quasiteroides, P. penetrans* and *P. thornei*) are found in 6 million hectares — or about 81% — of WA's cropping area.
- RLN species *P. neglectus* and *P. quasitereoides* can cause losses of up to 17% and 19% for barley and wheat, respectively.
- Climatic conditions favoured RLN in the 2014–15 seasons so damage was widespread. Root lesion nematode levels were high enough (medium to high infestation) to cause between 15 and 50% yield loss in 50% of all paddocks assessed (Figure 1).
- AGWEST Plant Laboratories can conduct in-season nematode diagnoses.

Science team

Dr Sarah Collins and Carla Wilkinson (Project leaders), Sean Kelly, Lucy Debrincat, Helen Hunter

Above: DAFWA Research Officer Dr Sarah Collins showing root development at a field day

Yield losses link to disease resistance ratings

Ratings for variety disease resistance provide critical information to growers to help manage foliar, root and nematode diseases in wheat and barley.

Less has been done in terms of yield losses due to these diseases and how these losses relate to resistance ratings. Current research aims to develop disease response curves for selected varieties of wheat and barley representing various resistance categories.

This collaborative national project coordinated by DAFWA is being delivered through six related modules led through five agencies. Modules ‘National coordination’ and ‘Wheat foliar diseases’ are being led by DAFWA staff Dr Rob Loughman and Dr Manisha Shankar, respectively.

Starting in 2014, crown rot experiments were established in the northern region, nematode set-up phases in the northern and southern region and a number of pilot foliar experiments were successfully completed in representative regions.

Intensive field experiments will be undertaken over the next four seasons to deliver yield response curves that reflect the effect of varietal resistance on impact of fungal diseases (crown rot, yellow spot, stagonospora nodorum blotch, septoria tritici blotch, wheat rusts, net blotch, scald, barley leaf rust, powdery mildew) and nematodes on wheat and barley.

The 2015 experimental program implemented protocols based on the methodologies and techniques developed in 2014. A full experimental program was deployed nationally, across all regions and through all modules, with collaborators delivering disease assessments, grain yield and grain quality measurements across the targeted range of root and foliar diseases. The statistical model for determining yield response curves in relation to disease measurements is being finalised.

This research will provide growers with vital information on crop resistance categories with actual and potential yield loss for key regional diseases, enabling growers to make better decisions in adopting suitable varieties and managing disease.

Funding and collaborators

GRDC, DEDJTR, QDAF, NSW DPI, Foundation for Arable Research Australia, Victoria

HIGHLIGHTS

- This national project aims to develop disease response curves for selected varieties of wheat and barley representing various resistance categories.
- A full experimental program is being deployed nationally, across all regions, with collaborators delivering disease assessments, grain yield and grain quality measurements across a targeted range of root and foliar diseases.
- The research will provide growers with vital information on crop resistance categories with actual and potential yield loss for key diseases, and will help growers decide on suitable varieties and manage diseases.

Science team

Dr Rob Loughman (Project leader), Dr Manisha Shankar, Geoff Thomas, Dr Kith Jayasena, Dr Daniel Huberli, Dr Sarah Collins, Ryan Varischetti

Above: Trial on yield loss from stagonospora nodorum blotch at South Perth depict clear varietal differences in resistance.

Below: DAFWA Director Dr Rob Loughman and DAFWA Research Officer Dr Manisha Shankar (first from the left and fifth from the right respectively) at a project team meeting in Horsham Victoria.

Providing decision support tools for consultants and growers

The cost of diseases of cereals, oilseeds and pulses is over $1.4 billion per year. Managing diseases at the right time with the right control techniques does substantially reduce the losses from disease and increases farm income. This project will provide the grains industry with tools and information packages to aid decisions to minimise production risk and increase returns.

Our focus is on disease management of sclerotinia and blackleg in canola and yellow spot in wheat using predictions from a better understanding of disease spread and damage.

Fungicide decision support tools for these key diseases are being to determine the best timing and predict the economic benefit of fungicide application. These decision tools are being field tested with groups of potential users across the country.

Crop disease models for stripe rust of wheat, ascochyta blight of lentils, powdery mildew of mungbean, wheat streak mosaic virus and beet western yellows virus of canola and pulses are being developed with project partners in SA, Vic, Qld and NSW. These models will become the basis for decision support tools for major grain crops across Australia.

This project currently provides a web and SMS service to guide growers across Australia to make more informed planting decisions of canola and field pea relating to blackleg and blackspot.

Decision support tools to help growers and their advisors apply fungicides at the optimal time are being developed and tested with project collaborators and industry for blackleg and sclerotina in canola and yellow spot in wheat. New prediction models are under development for important fungal and viral diseases of wheat, pulses and canola.

Funding and collaborators

GRDC, UWA, SARDI, DPI, DEDJTR, Marcroft Grains Pathology, USQ

HIGHLIGHTS

- A mobile decision app will bring paddock and season specific information to growers and agronomists in the field to maximise returns and minimise production risk for yellow spot in wheat and blackleg and sclerotinia in canola.
- Web and SMS services are guiding planting decisions for management of blackleg of canola and blackspot of field pea across Australia.
- New prediction models are under development for important fungal and viral diseases of wheat, pulses and canola.

Science team

Jean Galloway (Project leader), Dr Art Diggle, Dr Kawsar Salam, Geoff Thomas, Ciara Beard, Dr Ravjit Khangura, Dr Brenda Coutts, Pip Payne, Fumie Horiuchi, Dr Rebecca O'Leary

Right: DAFWA's new decision tool will help weigh your risks when managing Sclerotinia and Blackleg in canola.

Left: Blackspot leaf and stem symptoms.

PestFax: from paddock to print and back

PestFax is an interactive reporting service, providing risk alerts, current information and advice on pests, weeds and diseases threatening crops and pastures throughout the grainbelt.

PestFax received over 1200 reports of pests and diseases from the grains industry in the 2015 season. The service is provided by DAFWA and co-funded by the GRDC. The PestFax newsletter publishes weekly pest and disease updates throughout the growing season to around 1000 subscribers.

PestFax provides a direct link for the grains industry to DAFWA's experts in entomology, fungal diseases, viruses, weeds and nematodes. It provides readers with risk alerts, current information and advice.

The PestFax Map web tool shows the spatial distribution of reports of pests and diseases. The map is widely used by consultants and agronomists to alert their clients to prepare for likely pest and disease threats, and by chemical company representatives to support logistical movement of chemical stocks to where they will be needed.

Grain growers and agronomists can now report crop pests, diseases, weeds or other damage from their smart phone with the new PestFax Reporter app, helping to build a comprehensive picture of cropping issues during the season.

The app has been designed to quickly and easily report pests, diseases, weeds or other damage, like frost, by answering a set of straightforward questions.

The app also provides the opportunity to send a photograph of the cropping problem to aid identification or provide additional information.

The app can be used in locations outside mobile range, as the report is sent once the smart phone returns to an area with coverage or a connection to wifi.

These tools will improve management decisions by advisers, growers and industry personnel applicable to WA farm businesses by capturing accurate and representative field reports and delivering timely and regionally relevant information.

Funding

GRDC

HIGHLIGHTS

- The PestFax newsletter provides the latest reports and management information for insect pests, disease and weeds in the grainbelt.
- The PestFax Map web tool alerts industry to the spread of threats in their area.
- Grain growers and consultants can now quickly and easily provide reports or ask for identifications by using the new PestFax Reporter app.

Science team

Dr Darryl Hardie (Project leader), Cindy Webster, Svetlana Micic, Dr Dustin Severtson, Ciara Beard, Dr Kithsiri Jayasena, Dr Ravjit Khangura, Geoff Thomas, Dr Brenda Coutts, Dr Daniel Huberli, Dr Sarah Collins, Dr Art Diggle, Fumie Horiuchi, Alan Lord, Pip Payne, Jean Galloway

Right: Field walk in a paddock.

Left: DAFWA Research Officer Dr Art Diggle and Technical Officer Fumie Horiuchi using the PestFax Reporter mobile application.

You can fly, but you can't hide. A tactical approach to detecting and monitoring cabbage aphids in canola crops

The cabbage aphid is a serious pest of canola crops in spring, causing stunting, flower abortion and reduced seed set.

The ability to effectively detect and monitor canola crops for this pest using manual inspection and remote sensing techniques was investigated using a series of glasshouse, small plot and field studies.

An understanding of how arthropod pests distribute themselves in large agricultural fields is important because this affects how much effort is needed to detect and estimate their density. Experimentally released winged cabbage aphids displayed gradient effects from aphid release points and a non-random vertical distribution, with initial colonization occurring on the underside of lower canopy leaves and, later, highest numbers of cabbage aphids occurred on racemes.

Large-scale experiments showed strong edge effects with cabbage aphids mostly distributed along crop edges, including tree lines and contour banks. Using this information, a spatially-optimised sampling plan was developed. Furthermore, hyperspectral and multi-spectral imagery were investigated as a means of detecting cabbage aphid-induced stress, and potassium deficiency in canola as an indication of plant susceptibility to aphids. Leaf stress caused by moderate numbers of cabbage aphids on stem elongation growth stage canola was unable to be detected using hyperspectral imagery, indicating that cabbage aphids may go undetected on leaves and manual sampling is more reliable where early detection is important. Multispectral imagery acquired using an unmanned aerial vehicle successfully distinguished canola plants deficient in potassium, and demonstrated that deficient plants contained much higher numbers of green peach aphids than plants with sufficient potassium.

The cabbage aphid sampling plan is currently being incorporated into a smartphone application to allow for fast field sampling and automatic record keeping with a visual paddock mapping function to aid in timely and targeted application of insecticides.

Funding and collaborators

UWA, GRDC, University of California, CSBP Limited, Sensorem

HIGHLIGHTS

- Cabbage aphids were strongly aggregated along field edges, indicating that blanket sprays across entire crops may be unnecessary.
- A spatially-targeted sequential sampling plan was developed, which includes field stratification to account for variability associated with large field sizes and edge effects.
- This information provides a rapid means of assessing canola crops for cabbage aphid infestations and may provide a basis for targeted insecticide applications.
- Multispectral imagery acquired using an unmanned aerial vehicle demonstrated that potassium deficient canola plants could be detected and these were shown to be more susceptible to aphid attack.

Science team

Dr Dusty Severtson (Project leader)

Right: DAFWA Research Officers Dr Dusty Severtson and Dr Brenda Coutts using smart tech crop monitoring.

The dirt on snails and slugs

Snails and slugs are estimated cost to the grains sector in WA is about $3 million a year in lost production and control measures.

DAFWA is leading the research effort in WA to provide growers with region-specific information for effective timing of pest control. Our research will focus on the ecology, behaviours and biology of small pointed snails and black keeled slugs. The project will identify the environmental triggers for slug and snail activity to better predict the best time to bait.

Current research shows winter baiting of small pointed snails often requires more than one application. This is due to the snails only feeding on the baits if they come across them. In comparison, slugs can be managed by a single well-timed baiting event. However, timing is critical for both and baits need to be applied before slugs and snails lay eggs in order to break their life cycle.

Innovative 'blue sky' ideas were also trialled in the project. For instance, researchers tried microwave radiation to control the molluscs. It took 50 seconds to kill small pointed snails versus four seconds to kill a slug of 2cm or more. The amount of time it took to kill the snails means the energy expenditure is likely to make it uneconomical for broadacre cropping.

This project also investigated the efficacy of sprays that were registered for use for the control of snails in other crops both in Australia and overseas. No sprays were found to kill the snails or slugs. It appears the only chemical option is to bait.

DAFWA researchers will investigate the use of technology including automated rovers to produce paddock-scale maps of the distribution of snails and slugs. This will give growers the ability to target baits based on pest density.

The project will also determine if early mollusc damage in seedlings crops can be detected using remote technologies and will produce algorithms to measure bait distribution.

Funding and collaborators

GRDC, SARDI, Stirlings to Coast Farmers, Fitzgerald Biosphere Group, RAIN, Southern Dirt, SEPWA, DRD Royalties for Regions

HIGHLIGHTS

- Small pointed snails do not actively seek baits.
- Windrow burning can decrease snails.
- Sprays are not efficacious for slug or snail control.
- Baits are still the best option for snail and slug control.

Science team

Svetlana Micic (Project leader), John Moore, Tony Dore, Paul Matson, Laurie Wahlsten

Right: Research officer Svetlana Micic.

Left: Small pointed snails on the underside of a canola plant.

Making herbicide choice and application reliable and safe for growers

Herbicides are the main management tool for weed control in broadacre production systems of WA. Crop varieties are known to differ in their tolerance to herbicides and this can vary between regions or locations.

Small reductions in grain yield due to herbicide damage may be acceptable if weeds are strongly competing with the crop but yield reductions greater than 10% due to herbicide phytotoxicity may be as significant as weeds in limiting crop returns.

DAFWA researcher Dr Harmohinder Dhammu was part of a national herbicide-tolerance screening project (NSW, Qld, SA, WA) until early 2016. The project was designed to provide growers with clear information about herbicide interactions for individual varieties. for WA.

The project tested the tolerance to common in-crop herbicides on varieties of wheat, barley, oats, peas, chickpeas and lupin emerging from the National Variety Testing (NVT) program. This was to ensure that the tolerance to important herbicides is known at the time of a new variety's release.

The project also tested new chemistries on WA's common crop varieties in collaboration with chemical companies, and developed guidelines for the safe timing of old products like the phenoxy herbicides on new wheat varieties.

All crop varieties tested were tolerant to more than 70% of the registered herbicides at the label rates and timings. The remaining herbicides caused yield losses of 10–25% but in some cases up to 50%.

Drift of pesticides is of increasing community concern and strategies to mitigate drift without compromising efficacy or yield are being developed.

Science team

Dr Harmohinder Dhammu and John Moore (Project leaders)
Mark Seymour, Richard Snowball, Paul Matson,
Neville Chittleborough, Gerry Skinner, Kazue Tanaka,
Meg Slattery, Kevin Powis, Dr Kith Jayasena, Svetlana Micic

Funding and collaborators

GRDC, RIRDC, UWA, SARDI, UQ (CPAS)

HIGHLIGHTS

- A permit application based upon joint DAFWA and GRDC research is before the APVMA (Australian Pesticides and Veterinary Medicines Authority), which will allow oat growers to use trifluralin to manage ryegrass in oat crops for higher profitability.
- A series of genotype x environment x herbicide identical trials were simultaneously conducted across five states. These highlighted the degree of variation in herbicide response across environments and genotypes and showed agro-ecological region specific testing over longer periods would be advantageous.
- Results from all the herbicide tolerance trials can be accessed via NVT Online (www.nvtonline.com.au).
- Distribution of pesticides within the canopy using UV dyes and image analysis has allowed better recommendations for nozzles, adjuvants and setups to minimise drift while maintaining efficacy.
- SnapCard, a mobile phone app that growers can use to measure spray performance, was developed and tested in these projects.

Right: DAFWA Research Officer Dr Harmohinder Dhammu assessing field trials at Katanning.

Weed watch: alert for new and emerging threats

Changes in farming systems and practices have had an impact on the weed spectrum on many Australian farms. Infestations of new and emerging weeds have increased costs and yield loss for growers.

In many cases, little is known about the biology of new and emerging weed species. It is important that we understand the mechanisms (changes in biology and ecology) behind the emergence and spread of these summer and winter weed species. It is also important to understand if they have developed resistance to our most commonly used herbicide, glyphosate, and develop alternative ways to control them.

Three projects, all the result of national collaborations will deliver new knowledge on the biology and management of summer and winter weeds, and investigate their resistance evolution to multiple herbicide modes of action.

Widespread development of herbicide resistance in many Australian weeds has increased the focus on integrated weed management (IWM) systems. IWM requires a greater level of information on weed biology, including information on the longevity and general behaviour of weed seedbanks under local farming systems.

Weeds of local importance are the focus of a project that commenced in 2016. It is likely that the weed species the study will focus on include marshmallow, matricaria and feathertop Rhodes grass.

Recent research outcomes include:

- Button grass and tar vine are tough weeds that have a high level of dormancy. Finding ways to break seed dormancy is the key for future germination studies on these weeds
- Of nine sowthistle populations tested for resistance to glyphosate, three populations survived an application of 2L/ha Roundup Power Max. This indicates that these populations are already glyphosate resistant
- A weed survey of the WA grainbelt in late summer and early autumn of 2015 showed the most common roadside summer weed species were African love grass, fleabane, windmill grass and wild radish. The 2016 survey found 10 roadside infestations of feathertop Rhodes grass and one in-paddock infestation. In the eastern states, feathertop Rhodes grass is a serious weed species that has developed resistance to glyphosate
- At harvest, cutting the crop at 15 cm high removed 70% of brome grass seed, while almost no heads (or seed) of brome grass were removed if the crop was harvested at 35 cm high.

We will continue to investigate aspects of the biology and management options for new and emerging weed species. The weed survey has continued over the 2016/2017 summer to give us greater understanding of the occurrence and movement of new weed species.

Funding and collaborators

GRDC, UA, CSIRO, DPI, UQ

HIGHLIGHTS

- Three separate research projects are investigating the biology and management of 16 species of summer and winter weeds.
- Weed surveys are mapping common weeds and identifying future threats in the grainbelt.
- Some populations of summer weeds have already developed high levels of resistance to glyphosate.
- Finding ways to germinate weed seeds is a key to the performance of further research into the biology of these species.

Science team

Dr Abul Hashem and Alex Douglas (Project leaders), Dr Mohammad Amjad, Dr Catherine Borger, Cameron Wild, Dave Nicholson, Barbara Sage

Right: Chloris-virgata on roadside.

DAFWA Research Officer Dr Darshan Sharma discussing potential benefits of international germplasm in breeding crop varieties for WA.

Genetic Improvement Portfolio

The genetic improvement portfolio aims to improve the inherent potential in grains to protect and improve locally grown crops so the WA grains industry can consistently meet their quantity and quality targets.

In 2015/16, $9.5 million was invested in R&D through the portfolio by engaging 45 staff on 35 projects delivering across the WA grainbelt.

Our R&D focuses on plant characterisation (phenotyping), advancing crop improvement (pre-breeding), implementing marker assisted selection (MAS) and supporting breeding activities on wheat, barley, oats, lupins, field pea, canola and quinoa.

We are targeting traits for tolerance to abiotic stresses (frost, drought, heat, soil acidity, soil sodicity and salinity), disease resistance, grain quality, herbicide tolerance, yield stability and crop adaptation to WA growing conditions.

Our projects link to the grains industry through breeding companies, universities, CSIRO and grower groups. Strategic alliances including the Australian Frost Initiative and the Western Barley Genetic Alliance (Murdoch University and DAFWA) have been formed to spur synergies of co-location and collaboration.

Historically, crop genetics in DAFWA has delivered enormous industry outcomes directly through new varieties of cereals and pulses. Our latest release 'PBA Jurien' is an example of this.

The most popular wheat variety in WA (Mace), has a DAFWA variety (Wyalkatchem) as its major parent. We continue to work with industry to ensure the outcomes from our innovations are immense.

Our frost and drought benchmarking projects have developed standardised protocols that breeding companies can use, and variety rankings that enable growers to match varieties to locations and landscapes to manage frost.

White aleurone acid-tolerant barley lines recently identified through the Western Barley Genetic Alliance and the GMO grain crops currently being tested at our NGNE facilities are generating exciting developments that can be delivered through genetic improvements.

We have created lines with disease-resistance genes that enable new resistance genes and gene combinations to be readily moved into commercial varieties. These are being used by breeding companies to meet growers' demand for more resistant varieties. Newly developed resistant varieties will greatly reduce the estimated annual losses caused by crop diseases in WA and nationally.

Our future focus is on phenotypic evaluation, germplasm screening, genetic analysis, association mapping, production of doubled haploids, and development of improved germplasm for use by breeding companies.

Dr Darshan Sharma
Portfolio Manager


DAFWA frost researchers and collaborators at the West Dale trial site.

Stubble strategies mitigate frost damage

In 2014 GRDC established the National Frost Initiative to address three key areas in mitigating the effects of frost damage to crops – genetics, management and the environment.

The ‘Farming systems to improve crop susceptibility to frost’ project was a key part of the initiative. Led by DAFWA’s Ben Biddulph, this project established trials of farming practices that may have a potential to reduce frost damage by manipulating the soil heat bank, including canopy and stubble management, grazing and sowing direction.

Most of the trials were assessed in collaboration with partner organisations using large-scale precision agriculture in medium and low production environments.

One of the achievements has been to develop protocols for assessing and standardising frost damage that are now applied across the country. This has produced consistent datasets, allowing trials to be compared.

Research shows that by retaining stubble, crop canopy can be up to 0.5°C colder (and colder for longer) than areas with removed stubble. Results from the past four years indicate that stubble loads above 1.5t/ha in low production environments (2–3t/ha grain yield) generally increases the severity and duration of frost events and has a detrimental effect on yield under frost.

We observed that frost has a cumulative effect, that is, after successive frost events the level of damage increases. Also, with higher amounts of stubble retained, the duration the canopy experiences lower temperatures is longer.

In other findings, grazing trials indicated that two weeks of moderate and heavy grazing will delay flowering time of wheat and barley by up to a week, potentially reducing the risk of frost in a grain growers cropping program.

Future work includes investigating canopy management by altering the seeding and nutrition rates. Results from these trials are expected to be finalised over the next three years.

HIGHLIGHTS

- Standardised protocols have allowed for the comparison of uniform trials of frost mitigation in farming systems across southern Australia.
- Stubble loads of 1.5 t/ha in the low-production cropping regions low in the landscape can increase the severity and duration of frost events.
- Grazing for two weeks can delay flowering by up to one week in wheat and barley.

Science team

Dr Ben Biddulph (Project leader), Dr Sarah Jackson, Dr Dion Nicol, Brenton Leske, Mike Baker, Nathan Height

Funding and collaborators

GRDC, Birchip Cropping Group, ConsultAg, Facey Group, Fitzgerald Biosphere Group, DPI, Riverine Plains/FAR Australia, UA, WANTFA

Performance values a first for frost

Frost damage costs the Australian grain industry about $400 million annually through direct and indirect yield loss. In an effort to monitor the damage, frost susceptibility rankings for wheat and barley have been made available to Australian grain growers and advisors for the first time in 2016.

The Australian National Frost Program has assessed frost susceptibility of 72 wheat and 48 barley varieties in frost-prone environments at Wickepin WA, Loxton SA and Narrabri NSW. The research brings together an integrated program to address genetic, management and environmental approaches to frost mitigation.

In WA, along with Dr Biddulph, DAFWA's technical officer Nathan Height has been instrumental in planning, harvesting and collating the data that has contributed to the rankings. The information is available as an online interactive tool at nvtonline.com.au/frost.

Results from the past four years have shown that barley is more tolerant to frost than wheat and that susceptibility varies between wheat and barley varieties under mild frost events occurring from late booting to grain fill (Z49–75). The data used to determine the frost rankings is based on each variety's ability to maintain fertility under frost conditions at flowering.

The ranking information enables growers to make better informed frost management decisions when they adopt new varieties into their farming business. The frost performance ranking allows them to fine tune how they manage the new variety based on how they have managed past varieties with similar performance.

As part of this research, a decision-support framework was developed for managing frost and is available at grdc.com.au/ManagingFrostRisk.

Frost rankings are just one part of the overall pre-season frost management plan for growers to consider. Careful planning, zoning and choosing the right crops and enterprise mix to reflect the grower's risk profile continues to remain the best options to manage frost and is the focus of other ongoing research.

The program will continue benchmarking reproductive and stem frost susceptibilities in wheat and barley varieties and start screening international accessions of wheat to search for improved reproductive frost tolerance.

Funding and collaborators

GRDC, UA

HIGHLIGHTS

- Benchmarking of wheat and barley for frost susceptibility has shown barley is more frost tolerant than wheat.
- Variation in susceptibility exists within current wheat and barley varieties.
- Growers are advised to continue to select varieties based on yield in their environments, then use frost rankings to finetune risk management.

Science team

Dr Ben Biddulph (Project leader), Nathan Height, Mike Baker

Above: DAFWA Research Officers Dr Ben Biddulph and Dr Dion Nicol (second and fourth from left, respectively) with Dr Tim March and Dr Ariel Ferrante UA .

Below: Frost damage in barley.

Frost risk: managing wheat variety and sowing time

The key to maximising wheat yield with minimal frost damage is making the best variety choice for a given sowing time.

Growers are sowing an increasing portion of their crop early (or dry), raising concerns that this is pushing their crop into a higher frost risk.

Research by DAFWA staff as part of the GRDC National Frost Initiative has evaluated 72 wheat varieties and 36 barley varieties over sowing dates from mid-April to early June in 2014 at Wickepin and 108 wheat and 36 barley varieties in 2015 at Brookton.

In 2015, the highest yields of 3.0–3.5t/ha occurred when the crop flowered during the optimal flowering window. Most wheat varieties still maintained yields around 2 t/ha across a number a maturity classes, despite sustaining significant frost damage (50% frost-induced sterility (FIS)).

To assess the FIS on these varieties, a total of 45,660 wheat and 14,987 barley heads in 2014 and 76,512 wheat and 16,974 barley heads in 2015 were tagged at flowering and ear peep, and harvested five weeks later. Sterility was counted by hand.

In 2015, at the Brookton trial site, 29 frost events occurred that had screen temperatures below 2°C. Frost events occurred from mid-July to early October, demonstrating that in similar seasons there is no optimal time to sow to avoid frost due to its frequency in frost-prone parts of the landscape and unpredictable timing.

However, flowering in the optimal flowering window from mid-September to early October through matching variety to sowing time was the most important driver for maximising grain yield and profits.

Evidence suggests a general rule of thumb for the central WA grainbelt is to sow winter wheats in April (or earlier), long-season wheats from late April to mid-May, mid-season wheat from early May until mid-May and short-season wheat from mid-May (Figure 1).

Trials exploring similar interactions are being undertaken in South Australia and New South Wales.

HIGHLIGHTS

- More than 100 wheat lines were assessed for performance under frost in 2014 and 2016. These included commercial and experimental lines.
- Despite sustaining significant frost damage (>50% frost-induced sterility), wheat maintained reasonable yield levels when varieties were matched to sowing date.

Science team

Brenton Leske (Project leader), Dr Ben Biddulph, Dr Sarah Jackson, Dr Dion Nicol, Dr Karyn Reeves, Nathan Height, Mike Baker

Funding and collaborators

GRDC, UA, Living Farm, Kalyx Australia

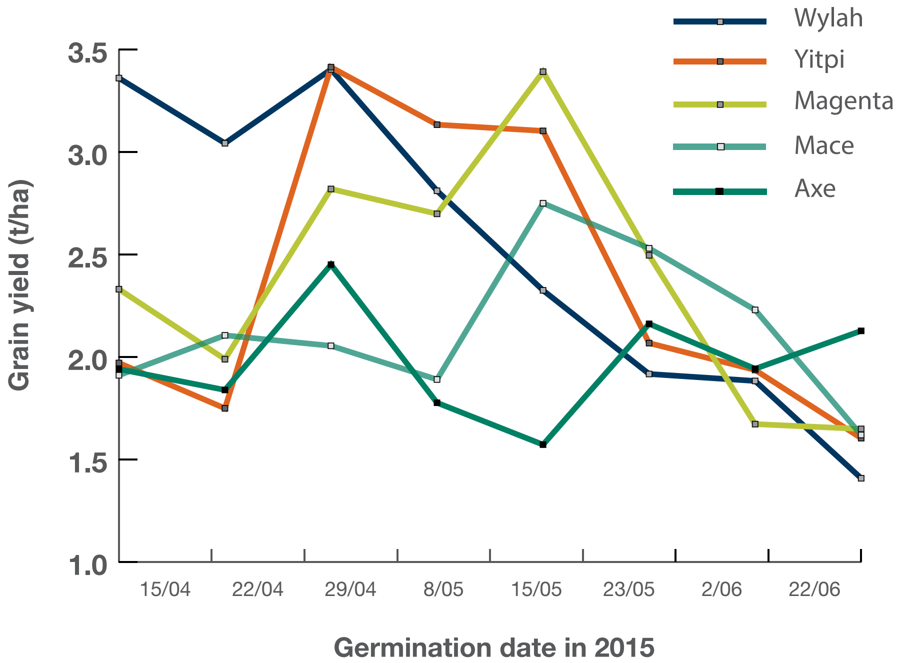


Figure 1. Grain yield response of representative short season (Axe), mid-season (Mace), mid-long season (Magenta), long season (Yitpi) and winter wheat (Wylah) in a frost-prone part in the landscape at Brookton 2015.

Note: sowing date = germination date due to irrigation.

Right: Collecting samples at West Dale frost trial site.

Genetic research cuts losses from wheat leaf diseases

Wheat diseases yellow spot (YS) and Stagonospora nodorum blotch (SNB) frequently occur together and present important resistance breeding targets. Nationally, they can cause annual losses of up to $676 million (YS) and $230 million (SNB).

Dr Manisha Shankar and Dr Michael Francki are leading national projects on YS and SNB, respectively. Their research focuses on understanding the genetic control and deployment of YS and SNB disease resistance in wheat that is suited to Australian production environments.

Project outputs will deliver new germplasm, associated DNA markers to track resistance genes and associated genetic knowledge for adoption by commercial breeders to improve resistance.

Yellow spot

Achievements in combating YS were made across several facets of research through the national collaboration including:

- developing improved phenotyping methods
- identifying 19 new resistance genes
- developing fixed lines with stacked resistance genes and delivering them to commercial breeding companies
- identifying elite lines with broad spectrum resistance
- improving understanding of the virulence structure of the pathogen.

Current research is focusing on elucidating the effects of individual resistance genes and gene combinations, evaluating effective resistance in multi-location and multiyear national trials, and developing resistance gene combination stocks in wheat relevant to northern, southern and western regions.

Stagonospora nodorum blotch

Significant progress has been made in SNB research to ascertain the genetic control of foliar and glume SNB resistance from different wheat origins and identification of DNA markers linked to genes.

Single and combined genes are being deployed in Australian wheat varieties and evaluated for SNB response in WA production environments. Global wheat accessions are being evaluated to identify alternative genes for further improvement to SNB resistance.

The project will deliver genetic products that enable commercial breeding companies to efficiently develop new varieties expressing improvements in SNB resistance. Grain growing will remain profitable when new wheat varieties are grown in paddocks under disease pressure.

Funding and collaborators

GRDC, UA, USQ, DEDJTR, CCDM, MU, TIA

HIGHLIGHTS

- Pre-breeding research has resulted in genetic resources available for improving disease resistance in commercial wheat breeding.
- Fixed lines with stacked YS resistance genes express greater resistance at both seedling and adult plant stages that is effective in various environments.
- Isogenic lines with different YS gene combinations will provide crucial information on the effects of individual genes and genes in various combinations within a similar background.
- The genetic control of SNB resistance is complex but advancements have been made to identify genes controlling foliar and glume resistance from different wheat origins.
- Genes with foliar and glume resistance to SNB are being evaluated for their effectiveness under disease pressure in WA production environments.

Science team

Dr Manisha Shankar (YS) and Dr Michael Francki (SNB) (Project leaders), Dorthe Jorgensen, Donna Foster, Hossein Golzar, Esther Walker, Chris McMullan, George Moore

Above: Yellow spot disease on wheat.

Below: DAFWA Research Officer Dr Michael Francki evaluates Stagonospora nodorum resistance at Northam site.

Managed Environment Facilities (MEF) enable putting the (index) finger on drought performance of wheat varieties

Drought is an ever-present constraint to wheat production in Australia. It is of particular concern in WA because so much of our wheat is produced in low rainfall areas and because of projected rainfall declines under most climate change scenarios.

Improving drought tolerance of wheat varieties is therefore an important priority for plant breeders. Equally important is for growers to know relative rankings of available varieties for water-stressed conditions.

Our managed environment facilities (MEFs) provide researchers with the required flexibility to create a range of seasons within the same year so that germplasm can be compared for inherited drought tolerance and relevant associated traits (phenotyping).

Research compared growth and yield of varieties currently in National Variety Trials and some advanced breeder's lines at DAFWA's Merredin MEF and two MEFs in New South Wales. Trials at each site were grown in two environments, one with natural rainfall and the other with supplementary irrigation applied after flowering.

Crop modelling was used to carefully choose the amount and timing of this irrigation to mimic a realistic but wetter season for that location. A drought index was calculated for each variety in each season/location combination as the positive or negative deviation from the regression between irrigated and rain-fed yields (Figure 1).

Like other quantitative traits, drought index also varies with seasons. In order to understand this and to enable breeding suitable varieties for the range of production environments in WA, we have analysed the relationships between drought index and crop traits, such as biomass production, harvest index, grain number and so on to determine which are important in different types of production environments.

This information will help growers choose the most adapted varieties for their environment and help plant breeders decide which traits are most worth focusing on.

HIGHLIGHTS

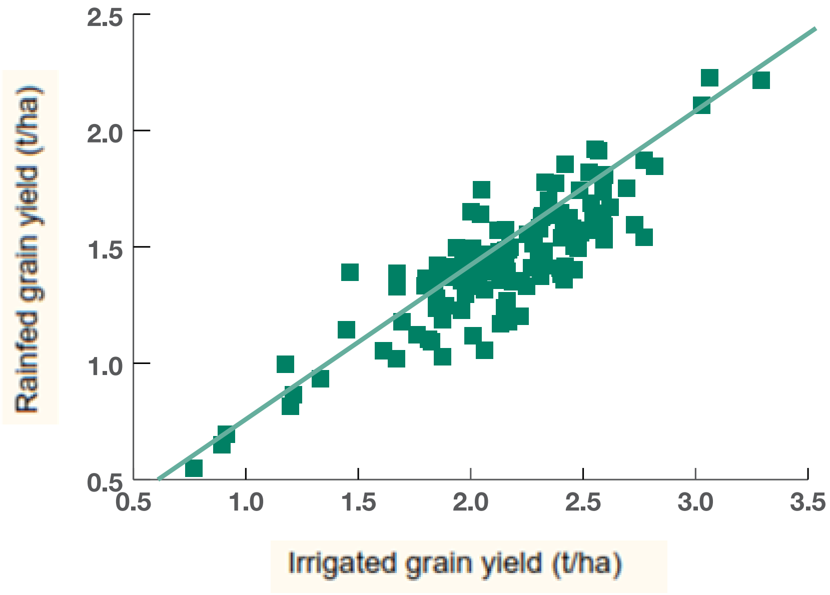
- Our managed environment facility provides opportunities to evaluate and compare germplasm under different water regimes keeping other things constant.
- Current NVT wheat varieties and advanced breeding lines were tested under rainfed and irrigated conditions at the three MEFs across Australia for five years.
- A drought index has been calculated from these data for each line in each environment.
- Plant traits associated with variability of drought index in different types of environment are being identified.

Science team

Dr Bob French and Mike Baker (Project leaders),
Dr Ben Biddulph, Dr Rebecca O'Leary, Glenn McDonald,
Shahajahan Miyan, Michelle Murfit,
Celia du Plessis

Funding and collaborators

GRDC, DPI, US, InterGrain, AGT, LongReach Plant Breeders, CSIRO, UQ



- Data points pertain to different varieties

- Varieties to the right and above the line yielded well under water limited conditions ("rainfed") but also responded to a spring soil moisture opportunity ("irrigated").

Figure 1. Grain yield with supplemented spring irrigation plotted against rainfed yield at Managed Environment Facility at Merredin in 2014.

Right: Merredin Managed Environment Facility.

Cracking the barley genetic code

An international consortium has cracked the barley genetic code, which will unlock greater potential to breed new, improved varieties.

DAFWA led the Australian contingent to decode chromosomes five and seven, two of the seven genetic units in the barley genome. These contain important genes controlling barley yield, malting quality, disease resistance and tolerance to frost. The consortium includes scientists from Australia, Germany, the UK, US, Japan, China, Finland and Denmark.

Sequencing the barley genome is a major milestone for Australian barley research and breeding and will provide unique opportunities for:

- isolation and characterisation of genes controlling yield, adaptation, quality, biotic and abiotic stress tolerance
- development of genome-wide molecular markers and genomic breeding tools
- understanding genetic and environmental interaction for barley adapted to climate changes.

Barley genomic information will help to improve selection processes, predict risks and, eventually, breed better varieties with higher yields, quality, greater tolerance to drought, frost and salinity, as well as resistance to pests and diseases.

Using the barley genome as reference, DAFWA researchers have also sequenced the genome of elite Australian barley varieties such as Hindmarsh. This will provide key information about which genes adapt barley to Australian environments to achieve maximum yield potential.

This research is one of the significant outputs of a new Western Barley Genetics Alliance between DAFWA and Murdoch University.

The results of this project will enable breeders and pre-breeders to access the barley genomic sequence and dissect genes for yield, adaptation, quality, biotic and abiotic stress tolerance. The millions of molecular markers generated in this project will make molecular marker-assisted breeding more accurate and efficient.

Future work will focus on developing gene based markers and associated genomic breeding tools that will broaden molecular breeding from single markers to genome-wide selection. Growers will then have access to adapted barley varieties with a significant yield potential and stability over current elite varieties.

Funding and collaborators

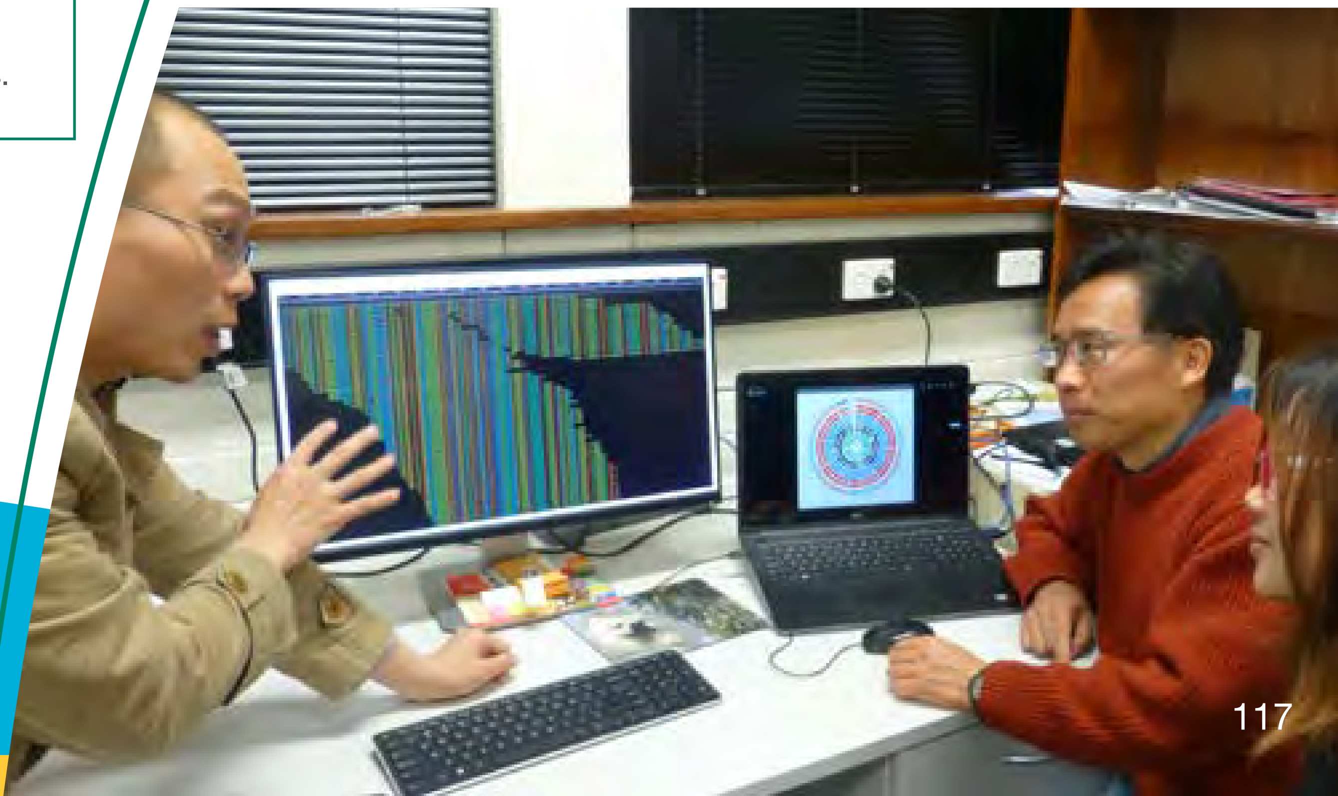
GRDC, International Barley Genome Consortium, MU, Max Planck Institute For Plant Breeding Research, The James Hutton Institute, Zhejiang University

HIGHLIGHTS

- The International Barley Genome Consortium assembled 4.8 billion pieces of barley genetic code, which represents about 95% of the barley genome sequence. DAFWA led the effort to complete two of the seven barley chromosomes.
- Over 39 000 barley genes were identified, which enabled us to answer some key scientific questions such as why barley is preferred over other cereals for malting and brewing.
- Key Australian barley varieties, Hindmarsh, La Trobe, Commander, Baudin and Vlamingh, were sequenced. Over two million genetic code variations were identified between Australian varieties. This work provides the basis to develop new tools for breeding in the future.
- Diagnostic molecular tools were developed for barley variety identity and purity tests, and also for molecular selection for agronomic and quality traits.

Science team

Professor Chengdao Li (Project leader), Sharon Westcott, Sue Broughton



Above: Barley team cracks the barley genome.

Below: Professor Chengdao with a graphic representation depicting the seven chromosomes of the barley varieties. The Australian consortium were responsible for the sequence of chromosomes 5 and 7.

Enhancing barley adaptation through new molecular markers for phenology

To maximise yield, crop growth and development processes need to match up with the growing season conditions (rainfall, temperatures and season length).

DAFWA and its collaborators are working towards generating germplasm, diagnostic tools and knowledge of the optimal phase development patterns (and thus the molecular ideotypes) for high-yielding barley varieties.

This will facilitate the development of new barley varieties with improved yield and yield stability.

Barley genotypes vary genetically for the period they require from planting to flowering and maturity. Combining desirable genes that underlie the variations in phase development and flowering behaviour (phenology) always has and will continue to play a core role in breeding better adapted barley varieties for Australian growers.

Large-scale experiments in both natural and controlled environments using 957 barley accessions, including 65 Australian barley varieties, were conducted. The same sets of materials were genotyped using up to 50,000 molecular markers. Key genes controlling phenology development and yield were identified through association mapping.

The project outputs will enable barley breeders to develop the next generation of barley varieties more efficiently. Barley growers will have improved knowledge to select suitable barley varieties for specific environments to achieve maximum yield and economic return.

To achieve this target, future work will focus on understanding the allelic variation of barley genes for yield and adaptation so that diagnostic molecular markers can be developed. We will also manipulate the key genes through new genome editing technology.

Funding and collaborators

MU, AGT, InterGrain, UA, UT

HIGHLIGHTS

- A comprehensive industry report has been created to document the past 20 years' research on grain yield and phenology development. Data on phenology traits, phenology genes and grain yield has been acquired from various sources, analysed and presented in the report.
- Eleven genes were identified to control phenology development and barley yield in various environments. Gene-specific molecular markers were developed.
- Genome-editing technology is being developed in the laboratory to manipulate key phenology genes.

Science team

Professor Chengdao Li (Project leader), Dr Dean Diepeveen, Max Karopoulos, Steve Brown, Lee-Anne McFawn, David Farleigh

Above: Professor Chengdao Li (far right) Professor David Morrison Murdoch University (left) with DAFWA Executive Director Dr Mark Sweetingham and Director Dr Rob Loughman discussing work being conducted by the Western Barley Genetic Alliance.

Below: DAFWA Research Officer Sue Broughton.

Genetic solutions to soil constraints and blue aleurone in barley

The Western Barley Genetics Alliance, a partnership DAFWA and Murdoch University, is a national leader in improving and understanding acid soil tolerance in barley.

In a series of projects aimed at improving the adaptation of barley to acidic soils, DAFWA researchers and collaborators led by Alliance director, Professor Chengdao Li, have screened thousands of barley lines for new sources of tolerance to acidic soils. These projects have developed new and improved gene-specific 'diagnostic' molecular markers to identify new tolerance alleles and genes in breeding populations.

This work also resulted in development of the variety Litmus™, which was the first acid-tolerant barley variety to be released in WA by plant breeding collaborators InterGrain and Syngenta.

Ongoing research will include developing improved tolerance in barley to acidic and alkaline soils using new sources of tolerance, and tackling the problem of blue aleurone – a blue colouring in the aleurone layer of barley grain (the layer immediately below the husk) present in some varieties including Litmus™. Although this trait does not affect yield or quality, Grain Trade Australia have nil tolerance for blue aleurone grain in malt barley deliveries and a maximum allowance of 1 in 100 grains in feed barley.

The gene for blue aleurone in barley is closely linked to the acidic soil tolerance gene, so potentially, many of breeding lines selected for acid soil tolerance might also express the undesirable blue aleurone trait.

The research team is using several approaches to solve the problem of blue aleurone in barley. New techniques are being employed so that the blue aleurone gene can be pinpointed and new molecular markers have been developed so that breeding programs can easily screen their breeding lines and eliminate lines with the undesirable gene.

Researchers have also identified lines with white aleurone and acidic soil tolerance. These strategies will enable breeders to develop the next generation of acidic soil tolerant barley varieties with white aleurone grain.

Future work will also explore tolerances to other soil constraints in barley including salinity, waterlogging and boron toxicity. Given that these abiotic stresses coexist in many soils, understanding the interaction of different tolerance genes is critical for further improvement of barley yield in different soils.

Funding and collaborators

MU, UT

HIGHLIGHTS

- Barley is sensitive to acid soils and soil acidity is one of the key limiting factors of barley yield improvement.
- Past and current research has demonstrated that a genetic solution, in combination with lime application, will provide the most efficient approach to enhance productivity in acidic soils.
- New sources of tolerance to acidic soils have been identified in barley and molecular markers are available to screen for the tolerance in breeding populations. New lines with white aleurone and acidic soils tolerance have now been successfully identified.
- Molecular markers have been developed for blue aleurone and will provide an effective tool for breeders to overcome the blue aleurone issue.

Science team

Professor Chengdao Li (Project leader), Sue Broughton, Sharon Westcott, Lee-Anne McFawn, Steve Brown, David Farleigh

Above: Identifying barley lines with water logging tolerance.

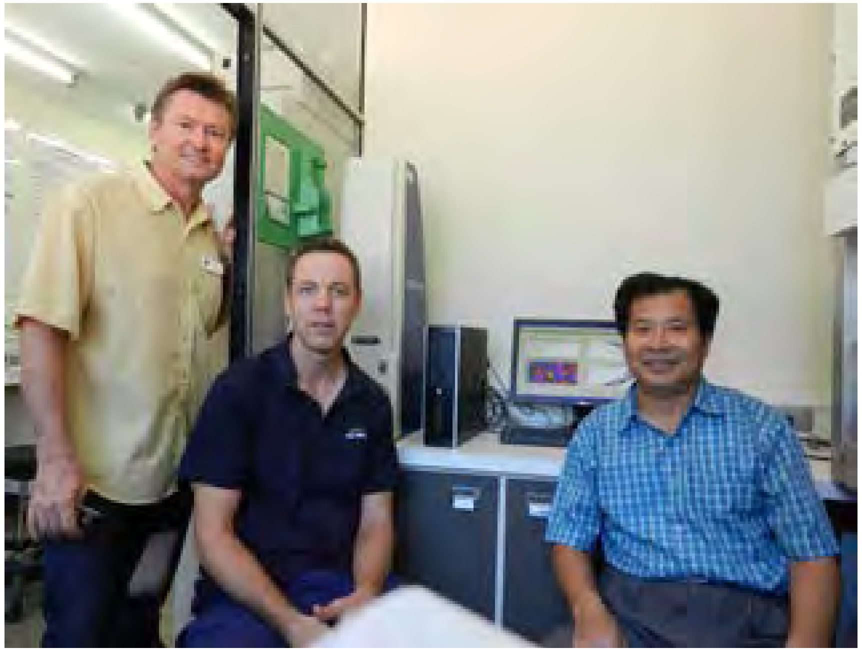
Below: DAFWA Research Officer Sue Broughton in a glass house in South Perth.

DNA markers accelerate lupin breeding

Lupin is the most important grain legume for acid, well-drained, light-textured soils in southern Australia.

It provides a viable break crop by controlling disease and weeds in cereal rotations and provides legume N and on-farm stubble and seed for stock and aquaculture feed. This humble grain could also be the next big health food for people.

But yield improvements are required in both current and potential lupin-growing regions to increase farm profitability.



Our research aims to increase breeding efficiency for higher yield by developing molecular markers for yield and yield-promoting traits in narrow-leafed lupin and additionally to provide new yield, phenology, plant vigour and drought tolerance related traits to core lupin breeding programs.

We aim to understand plant traits that confer higher yield across a wide range of environments, with the intention to improve lupin breeding outcomes for all southern states.

Evidence suggests that yield potential in longer season environments could be improved by incorporating a broader range of flowering time responses to temperature and day length.

The project is using diverse sets of backcross and elite inbred lines, many incorporating wild alleles from several Mediterranean countries of origin to mine genetic variation for yield-related traits.

Seven quantitative trait loci (QTLs) linked to lupin yield have been identified so far in a Unicrop x Tanjil recombinant inbred line population. Additionally, a relatively wide range of flowering times have been demonstrated in backcross populations in the elite Mandelup genetic background.

Funding and collaborators

GRDC, CSIRO, UWA

HIGHLIGHTS

- Lupin breeding will benefit from the identification of new loci for grain yield to improve efficiency of narrow-leafed lupin breeding.
- New yield-related traits will be identified that will broaden the adaptation of lupins to different growing regions in Australia.

Science team

Dr Jon Clements (Project leader), Dr Huaan Yang, Daniel Renshaw

Right: Flowering lupin in backcross populations in the field at Wongan Hills Research Station.

Left: Dr Jon Clements, Daniel Renshaw and Dr Huaan Yang in the molecular marker laboratory at DAFWA.

Star performer: PBA Jurien yield improvement

The national lupin breeding program led by DAFWA until July 2016, has continued to breed narrow-leafed lupins to support this major industry in Australia.

Lupin is a major grain legume known primarily for:

- its high protein seed as an animal feed
- its ability to fix N and to grow on infertile, sandy soils
- and its value in growing season rotations with cereal grains, hay, oilseeds, pulses and pastures as a break crop.

There is increasing interest in lupins as a healthy human food ingredient.

DAFWA release the variety PBA Jurien in 2015. Jurien is a high-yielding Australian sweet lupin variety suitable for all lupin-growing areas of Australia, and provides a significant yield improvement over current varieties in most of these regions.

Across WA, it had an average yield advantage of 5% in Agzones 1-8 over the previous variety, PBA Barlock. It is a variety with good anthracnose (R), phomopsis (R) and grey spot resistance (R), with tolerance to metribuzin (superior to long-running variety Mandelup and similar to Coromup), early flowering and early maturity, and good grain quality parameters that on average meet market requirements.

PBA Jurien (tested as WALAN2385) was bred and progressed by Dr Bevan Buirchell, Dr Jon Clements and Dr Huaan Yang, along with the lupin breeding technical team at DAFWA.

Valuable collaboration from Mark Richards (NSW DPI), Andrew Ware (PIRSA–SARDI) and Alan Meldrum (Pulse Australia) is acknowledged. PBA Jurien is from a 2003 cross, 03A013R-ARR1-54, between 03L F1 female bulk 1 and 95L335-17-15 (=WALAN2231).

It was named after the coastal town of Jurien Bay, which is adjacent to major lupin-growing regions in WA. The variety is the latest in a series of about 25 varieties released historically in WA through DAFWA.

In an important breeding first for Western Australia and Australia, DAFWA together with GRDC selected and appointed Australian Grain Technologies (AGT) as the licensee for further development of DAFWA and GRDC's jointly owned commercial lupin breeding germplasm. AGT brings a wealth of crop breeding experience and technology capability to help propel lupin productivity and potential regionally, nationally and internationally.

The DAFWA/GRDC lupin breeding program will make two final variety releases as the breeding material then transitions to AGT. DAFWA will continue to focus on pre-breeding genetics with the support of GRDC and partners in the future.

Funding and collaborators

GRDC, DPI, WWAI, SARDI, Seednet, PBA

HIGHLIGHTS

- PBA Jurien provides a yield improvement of approximately 5% in WA and 2% in NSW and SA over the previous lupin variety.
- For growers who were still growing the older popular variety, Mandelup, the yield increases of PBA Jurien are a good reason to change up to the latest variety.

Science team

Dr Jon Clements (Project leader), Dr Huaan Yang, Geoff Thomas, Cliff Staples, Simon Rogers, Michelle Priestley, Leanne Young, Daniel Renshaw, David Robertson, Ryan Varischetti, Remo Precopio, Tracey Mouritzen, Leigh Smith, Charlotte Roigt

Above: Lupin seed.

Below: From left: Alan Meldrum (Pulse Australia) with DAFWA Research Officers Geoff Thomas, Jon Clements and DAFWA Technical Officers Leigh Smith, Leanne Young, Tracey Mouritzen, Charlotte Roigt, Michelle Priestley, Daniel Renshaw and Cliff Staples.

Fast-forward breeding with doubled haploids

Experts at DAFWA are fixing the genetics of wheat and barley plants using specialist plant tissue culture techniques and doubled haploid technology that is faster than conventional breeding methods. The resulting ‘doubled haploid’ lines are a valuable tool in plant breeding and research.

Our research has refined the method for wheat and barley doubled haploid technology. The essential step of generating fixed (true-breeding) lines following hybridisation or ‘crossing’ parental varieties is reduced from 4-5 years using conventional breeding methods, to less than 12 months using plant tissue culture techniques.

For plant breeders who can make rapid advances working with fixed lines, the technique can shave years off the time to deliver a new variety.

Doubled haploids are also extremely useful in genetic studies, gene mapping and the development of molecular markers and are often preferred over conventional inbred lines due to their 100% homozygosity.

Doubled haploid populations are an important part of our research, the fact that they are homozygous or ‘true-breeding’ lines means that they can be multiplied and reproduced without genetic change occurring.

These populations allow for replicated trials being conducted across different locations and years and are therefore ideal for mapping complex quantitatively inherited traits such as resistance to necrotrophic foliar diseases in wheat.

The laboratory has grown considerably in the past five years, supplying large numbers of doubled haploid lines annually to LongReach Plant Breeders as well as to researchers from DAFWA, Murdoch University, Curtin University and interstate groups at the South Australian Research and Development Institute (SARDI), Australian Centre for Plant Functional Genomics (ACPFG), the CSIRO and the University of Adelaide.

In 2016, over 25 000 plants were produced from tissue culture and transplanted to soil. However, there are still challenges. Not all these plants develop into fertile doubled haploid plants and varieties can vary in their response to the tissue culture process so we are working with industry to optimise the protocol for all varieties.

HIGHLIGHTS

- Microspore-based techniques are used where immature pollen cells (microspores) are diverted from their normal developmental pathway to one of embryogenesis and haploid plant development. Following a chromosome-doubling step, the resulting doubled haploids are fully fertile and 100% homozygous at all loci.
- DAFWA's Cereal Doubled Haploid Program provides a national fee-based service to develop wheat and barley doubled haploid lines for breeders and cereal researchers.
- The DAFWA program is currently the only laboratory producing barley doubled haploids and one of only two wheat doubled haploid laboratories in Australia.

Science team

Sue Broughton (Project leader), Li Liu, Julie Killen

Abovet: Double Haploid populations.

Below: DAFWA Technical Officer Li Liu with the double haploid populations at South Perth.

Quinoa research explores potential for ‘superfood’ crop

The superfood quinoa is a warm season crop suited to irrigation that is showing potential in rainfed environments of the WA grainbelt.

DAFWA research aims to test the adaptation of quinoa at a variety of locations across Australia and potentially make a variety available to growers.

The project’s objectives include:

- transitioning quinoa from a niche, cottage and organic crop to wider adoption across broadacre farming environments by undertaking field testing that may lead to the development of variety options
- developing and providing knowledge on agronomy, production and seed processing to growers and industry.

Field testing is underway in the south-east of SA, central southern NSW, Katherine and Alice Springs in the NT, and Kununurra, Mingenew and Cunderdin in WA.

Trials will initially test suitability to either irrigated or rainfed environments and investigate a range of sowing times, seeding rates and N applications. Simultaneously, herbicide tolerance trials are under way to find suitable options to use in quinoa crops. This research is particularly important in southern Mediterranean-type environments where winter growth of quinoa is slow.

Second-stage variety type trials will test advanced lines developed in earlier work against a number of germplasm lines donated by the USDA Genebank and multiplied at Manjimup and Kununurra. Variety Medusa, owned by Australian Grown Superfoods, has been made available for the national variety trials.

Germplasm and agronomic evaluation trials are being undertaken in NSW, NT, Kununarra and south western WA in 2016 and 2017.

Funding and collaborators

RIRDC, SARDI, DPI, DPIF

HIGHLIGHTS

- Quinoa seed is called a 'superfood' because it has an excellent balance of amino acids, is high in minerals, vitamins and fibre, and is gluten free.
- Seeds are covered in bitter-tasting saponins that can be washed off easily before cooking.
- While quinoa grows well in warm environments, its performance in winter rainfed environments in southern Australia needs to be evaluated.
- Weed control will be critical for the successful adoption of quinoa in broadacre cropping systems.
- New varieties suited to Australian conditions could be developed and made available to growers.

Science team

Richard Snowball (Project leader), Mark Warmington, Dr Harmohinder Dhammu, Mario D'Antuono, Dr Darshan Sharma

Above: Richard Snowball with quinoa plants in the glasshouse.

Below: Harvesting a quinoa field trial at the Frank Wise Institution, Kununurra.

Merredin Research Station field day.

Field Research Services Portfolio

Field research services (FRS) ensures the delivery of timely and efficient technical expertise to implement field research experiments across the WA grainbelt.

Our team has specialist capability to undertake complex field-based experiments, phenology and physical crop measurements and use of a range of scientific grains research equipment.

We operate seven field research units to manage R&D experiments for DAFWA, CSIRO, universities and privately funded grains research projects.

Our FRS team team delivers expertise in:

- Field research experiment management – trial site selection, seed preparation, sowing, pre- and post-emergence weed, disease and pest control treatments, trial observations and harvesting
- Trial seed production and multiplication – small quantities of seed are obtained from breeding companies and field experiments each year. The seed is cleaned and multiplied for experiments in the following year
- Management of field research facilities and land for field research – research facilities are managed and maintained for field experiments, particularly in situations considered unsuitable for growers paddocks due to unacceptable risks associated with intellectual property; biosecurity implications (disease trials); prevalence of weeds, pests and diseases; unregistered herbicides and fungicides; and genetically modified organisms
- Establishment and management of research facilities.

Research projects frequently need the establishment of new field operations and infrastructure. Our team ensures the timely commencement and implementation of new research field projects taking a lead role in the procurement of land and infrastructure to support field-based grains R&D activities.

We also manage DAFWA's New Genes for New Environments (NGNE) facilities located at Merredin and Katanning, which enable trialling of GM crops in a variety of environments, and the managed environment facility (MEF) located at Merredin, which allows water use efficiency traits to be evaluated under a range of heat and drought conditions within any year.

FRS will continue to develop its capability and equipment to manage the complexity and technologies involved in establishing and managing field experiments, applying investigative treatments, evaluating crop growth and development, and other field measurements. Our expertise will evolve to tackle cutting-edge applied grains R&D.

Ian Pritchard
Portfolio Manager

Technical Team: Stephen Cosh, Julie-Anne Roche, Vincent Lambert, Steve Bell, Colin Norwood, Larry Prosser, Trevor Bell, Bruce Thorpe, Shari Dougall, Tracey Mouritzen, David Allen, Laurie Maiolo, Daniel Cox, Russell Quartermaine, Chris Matthews, Jolie Delroy, Max Karopoulos, David Farleigh, Chiquita Butler

Merredin Managed Environment Facility

Water productivity traits are evaluated under a range of heat and drought conditions within any year at the Merredin managed environment facility (MEF).

This research assists in fast-tracking selected new traits to be incorporated by breeding companies into higher yielding crop varieties for growers, ensuring they remain profitable into the future.

These improvements will be increasingly important given climate change predictions for the lower rainfall environments.

Merredin MEF represents the lower rainfall environments across southern WA, South Australia, and the Victorian Wimmera and Mallee regions, which between them produce the majority of Australian grain.

The national MEF program has currently evaluated wheat for a range of traits (Table 1). It is envisaged that a range of crops including barley, oats, canola, legumes and lupins, will be evaluated at MEF facilities in future.

Table 1. Trials/projects evaluating physiological traits of wheat at Merredin MEF 2014-2016

MEF trial description	2014	2015	2016
Benchmarking of water productivity traits	✓	✓	
Validating the role of the wheat 1-FEH gene in stem water-soluble carbohydrate remobilisation to the grain	✓	-	-
Identification of genetic variation for heat tolerance in durum and bread wheat	✓	-	-
Engagement of the national MEF in valida-tion and delivery of key physiological traits for improved wheat performance under drought	✓	-	-
Genetic variability in wheat and barley for establishment and early growth under limit-ing soil moisture	✓	-	-
Alternative dwarfing gene phenotyp-ing/gene value experiment	-	✓	✓
Rate of grain filling phenotyping/trait value experiment	-	✓	✓
Maintenance of leaf area phenotyping/trait value experiment	-	✓	✓
Transpiration efficiency x WSC trait combi-nation value experiment	-	✓	✓
Early vigour	-	✓	-

Funding and collaborators

GRDC, CSIRO, UT, DPI, AGT, MU

HIGHLIGHTS

- Merredin MEF comprises 60 ha of land in rotation with 21.6 ha of land developed for irrigation by mobile travelling irrigators.
- Water for irrigation is guaranteed independent of seasonal rainfall. Water is primarily sourced from a 16 ML dam and a 12-ha roaded catchment with access to the Goldfields Pipeline, when required.

Science team

Ian Pritchard (Project leader), Vincent Lambert, Michelle Murfit, Salzar Rahman, Matthew Mills

Right: Field plots under irrigation in the managed environment facility of Merredin.

Field experiments in the New Genes for New Environment facility at Merredin.

New Genes for New Environments (NGNE) Facilities

DAFWA's New Genes for New Environments (NGNE) facilities are designed to enable evaluation of the world's best genetic modification traits from both public and private research organisations under WA conditions in a highly contained and safe testing environment.

NGNE facilities are located at Merredin and Katanning. These two sites have different climates and soils that enable trialling of GM crops in a variety of environments. These locations provide contrasting stresses such as low rainfall and high temperatures in Merredin with frost and winter waterlogging in Katanning.

The NGNE centres at Merredin and Katanning have a range of facilities and experimental research equipment used to work on GM crops. These include trial areas as well as work areas, offices and laboratories.

NGNE facilities and services include:

- a 5ha trial site enclosed by bird-proof netting and a 2m-high fence to exclude large animals
- an electronic security system
- an onsite secured shed housing machinery used in GM trial work and seed production
- a clean-down pad with air and water pressure cleaners to ensure all equipment is thoroughly cleaned to further prevent GM material leaving the secured site
- a physical containment Level 2 (PC2) laboratory that is fully equipped for analysis of GM plant material in a safe and contained environment, including an autoclave room for destruction of surplus viable plant materials.

All staff are trained to meet the Office of Gene Technology Regulator licence requirements and GM crop trial work is overseen by a compliance manager.

In partnership with the Australian Centre for Plant Functional Genomics (ACPFG), DAFWA is testing traits for drought, aluminium toxicity, subsoil salinity tolerance and bio fortification of seed zinc and iron.

HIGHLIGHTS

- New Genes for New Environments facilities are located at Merredin and Katanning.
- The NGNE provides a highly contained and safe testing environment for GM traits.

Science team

Ian Pritchard (Project leader), Dr Ed Barrett-Lennard, Dr Modika Perera, Vincent Lambert, Steve Bell Adrian Cox, Meir Altman, Leigh Smith

Funding and collaborators

ACPFG

Making sense of data: Biometrics

Grains research produces a large amount of data and the DAFWA biometrics team is focused on ensuring robust design of experiments and accurate analysis of experimental data to maximise the impact of research for industry.

Biological data can be impacted by many factors and it may be difficult to interpret what effects are 'real'. Biometrics is the science of applying statistical analysis to biological data and it enables us to quantify experimental outcomes. It is an essential component of quality agricultural research.

Our team of biometricians help ensure that:

- Experiments are well designed and address the questions of interest
- Data is analysed appropriately to provide accurate estimates
- Correct messages are conveyed from the research to growers
- Decision tools are built based on sound statistical models
- The team assists research projects from beginning to end by helping with experimental design, statistical analysis, model development and interpretation of results.

DAFWA Biometricians play a crucial role in most research undertaken by the grains team and are involved in:

- providing a statistical service to research groups in the areas of agronomy, pathology, pests and weeds, farming systems, frost, climate and more
- development of web based decision tools to help with management decisions in grain production. New tools are being developed that will predict the impact of climate, nutrient inputs and diseases
- strengthening the skills of research staff through course delivery, presentations and individual consultations
- advice on the design and analysis of larger scale on-farm experiments.

The biometrics team is focused on ensuring robust experimental designs followed by appropriate statistical models that account for the inherent variability in agricultural data, with the ultimate aim of maximising the impact of research for the industry.

Advances in technology and statistical software are allowing novel approaches to capture, visualise and analyse data.

Funding and collaborators

GRDC, DRD Royalties for Regions, SAGI, DAF Qld, UA, University of Wollongong, VSN International

HIGHLIGHTS

- Collaboration with a biometrician from the beginning to the end of projects ensures scientifically valid and reliable results.
- Sound experimental design and analysis is critical for accurate messages to industry.
- Our biometrics team help deliver quality research and tools to support grower decision making.

Science team

Andrew van Burgel (Project leader), Mario D’Antuono, Dr Katia Stefanova, Dr Rebecca O’Leary, Dr Karyn Reeves, Dr Kefei Chen, Dr Fiona Evans

Right: DAFWA Biometrician Mario D’Antuono (left) and Research Officer Dr Darshan Sharma have developed a new online tool, MyPaddock, for grain growers to address wheat production problems.

List of common acronyms/abbreviations

Definition	Acronym
Three dimensional	3-D
Australian Centre for International Agricultural Research	ACIAR
Australian Centre for Plant Functional Genomics	ACPFG
Australian Export Grains Innovation Centre	AEGIC
Australian Grain Technologies	AGT
Aluminium	Al
Application programming interface	API
Australian Pesticides and Veterinary Medicines Authority	APVMA
Botanic Gardens and Parks Authority	BGPA
Centre for Crop and Disease Management at Curtin University	CCDM
Centimetres	cm (e.g 12cm)
Council of Australian Grain Grower Organisations	COGGO
Centre for Pesticide Application and Safety (CPAS) at the University of Queensland	CPAS
Centre for Rhizobium Studies at Murdoch University	CRS
Commonwealth Scientific and Industrial Research Organisation	CSIRO
Controlled traffic farming	CTF
Copper	Cu
Department of Agriculture and Fisheries, Qld	DAF Qld
Department of Agriculture and Food Western Australia	DAFWA
Diammonium phosphate	DAP
Department of Economic Development, Jobs, Transport and Resources, Victoria	DEDJTR, formerly DEPI
Department of Environment, Land, Water and Planning (Vic.)	DELWP
Department of Primary Industries (NSW)	DPI
Department of Primary Industry and Fisheries NT	DPIF
Department of Regional Development Royalties for Regions	DRD
Foundation for Arable Research Australia, Victoria	FAR Australia
Far East Agricultural Research Group	FEAR

Definition	Acronym
Frost induced sterility	FIS
Field Research Services	FRS
Grams	g (e.g. 10g)
Grower Group Alliance	GGA
Grains Industry Group	GIG
Grains Industry Association of Western Australia	GIWA
Genetically modified	GM
Genetically modified organism	GMO
Grains Research and Development Corporation	GRDC
Gross value of agricultural production	GVAP
Hectares	ha (e.g. 5000ha)
Integrated Farming Systems	IFS
iPhone operating system	iOS
Integrated weed management	IWM
Kilograms	Kg (e.g. 7kg, 3kg/ha)
Kilograms per hectare	Kg/ha
Litres	L (e.g. 2L)
Metres	m (e.g. 10m)
Merredin and Districts Farm Improvement Group	MADFIG
Monoammonium phosphate	MAP
Marker assisted selection	MAS
Management Environment Facility	MEF
Mingenew–Irwin Group	MIG
Millilitres	mL
Millimetres	mm (e.g. 2mm)
Manganese	Mn
Molybdenum	Mo
Moderately susceptible	MS

Definition	Acronym
Moderately susceptible to susceptible	MSS
Murdoch University	MU
Northern Agri Group	NAG
Nitrogen	N
Northern agricultural region	NAR
National Frost Initiative	NFI
New Genes for New Environment	NGNE
Natural resource management	NRM
New South Wales	NSW
National Variety Testing	NVT
Office of Gene Technology Regulator	OGTR
Phosphorous	P
Pulse Breeding Australia	PBA
Physical containment level two	PC2
Potential of hydrogen	pH
Doctor of Philosophy	PhD
Pre-harvest sprouting	PHS
Queensland	Qld
Quantitative trait loci	QTL
Resistant	R
Research and development	R&D
Ravensthorpe Agricultural Initiative Network	RAIN
Regional Cropping Solutions Network	RCSN
Research, development and extension	RD&E
Rural Industries Research and Development Corporation	RIRDC
Root lesion nematode	RLN
Return on investment	ROI
Round up Ready	RR
Susceptible	S

Definition	Acronym
South Australia	SA
Statistics for the Australian Grains Industry	SAGI
South Australian Research and Development Institute	SARDI
South East Premium Wheat Growers Association	SEPWA
Short message service	SMS
Tonnes	t (e.g. 2000t)
Tonnes per hectare	t/ha (e.g. 5t/ha)
Tel Aviv University - Institute for Cereal Crops Improvement ICCI	TAU
Tasmanian Institute of Agriculture	TIA
University of Adelaide	UA
Unmanned aerial vehicle	UAV
University of California	UC
University of South Australia	UniSA
University of New South Wales	UNSW
University of Wollongong	UoW
University of Sydney	US
University of Southern Queensland	USQ
University of Tasmania	UT
University of Western Australia	UWA
Victoria	Vic
Western Australia	WA
Western Australia No-Tillage Farmers Association	WANTFA
Wagga Wagga Agricultural Institute	WWAI
Zhejiang University, China	ZJU
Zinc	Zn

Collaborators

Agvivo

Australian Centre for Plant Functional Genomics

Australian Grain Technologies

Birchip Cropping Group

Botanic Gardens and Parks Authority

Central West Farming Systems (NSW)

Centre for Crop and Disease Management at Curtin University

Centre for Pesticide Application and Safety (CPAS) at the University of Queensland

Centre for Rhizobium Studies at Murdoch University

Commonwealth Scientific and Industrial Research Organisation

ConsultAg

Council of Australian Grain Grower Organisations

CSBP

Department of Agriculture and Fisheries, QLD

Department of Economic Development, Jobs, Transport and Resources, Victoria

Department of Environment, Land, Water and Planning (Vic.)

Department of Primary Industries (NSW)

Department of Primary Industry and Fisheries NT

Department of Regional Development Royalties for Regions

Desiree Futures

Facey Group

Far East Agricultural Research Group

Fitzgerald Biosphere Group

Foundation for Arable Research Australia, Victoria

Grains Research and Development Corporation

Grains Industry Group

Gillamii Centre

GXE Crop Research

Imtrade

InterGrain

International Barley Genome Consortium

Kalyx Australia

Landmark

Liebe Group

Lime WA Inc

Living Farm

LongReach Plant Breeders

Merredin and Districts Farm Improvement Group

Marcroft Grains Pathology

Max Planck Institute For Plant Breeding Research, Germany

Merredin Dryland Farming Group

Mingenew–Irwin Group

Mullewa Dryland Farming Initiative

Muresk Institute

Murdoch University

Northampton Agriservices

Northern Agri Group
Precision Agriculture
Precision Agronomics Australia
Pulse Breeding Australia
Ravensthorpe Agricultural Initiative Network
Regional Cropping Solutions Network
Riverine Plains
Rural Industries Research and Development Corporation
Rural Solutions SA
Seednet
SoilsWest at University of Western Australia
South Australia Research and Development Institute
South East Premium Wheat Growers Association
Southern Dirt
Southern Farming Systems (Vic)
Statistics for the Australian Grains Industry
Sensorem
Tasmanian Institute of Agriculture
The James Hutton Institute, UK
Thinkspatial
University of Adelaide
University of California
University of South Australia
University of Southern Queensland
University of Sydney
University of Tasmania
University of New South Wales
University of Western Australia
University of Wollongong
University Tel Aviv - Institute for Cereal Crops Improvement ICCI
VSN International
Wagga Wagga Agricultural Institute
West Midlands Group
West Arthur Trials Group
Western Australia No-Tillage Farmers Association
Yuna Farm Improvement Group
Zhejiang University, China

Scientific journals

Alharby, H. F., Colmer, T. D., & Barrett-Lennard, E. G. (2014). Salt accumulation and depletion in the root-zone of the halophyte Atriplex nummularia Lindl.: influence of salinity, leaf area and plant water use. Plant and soil, 382(1-2), 31-41.

Ahmad, A., Thomas, G.J., Barker, S.J. and MacLeod, W.J., 2016. Genotype resistance, inoculum source and environment directly influence development of grey leaf spot (caused by *Stemphylium* spp.) and yield loss in narrow-leafed lupin (*Lupinus angustifolius*). *Crop and Pasture Science*, *67*(1), pp.81–90.

Asseng, S., McIntosh, P.C., Thomas, G., Ebert, E.E. and Khimashia, N., 2016. Is a 10-day rainfall forecast of value in dry-land wheat cropping?. *Agricultural and Forest Meteorology*, *216*, pp.170–176.

Babatunde, O., Armstrong, L., Leng, J. and Diepeveen, D., 2015. A survey of computer-based vision systems for automatic identification of plant species. *Journal of Agricultural Informatics, 6*(1), pp.61–71.

Babatunde, O., Armstrong, L., Leng, J. and Diepeveen, D., 2015. Comparative analysis of genetic algorithm and particle swam optimization: An application in precision agriculture. *Asian Journal of Computer and Information Systems, 3*(1), pp.1–12.

Barrett-Lennard, E. G., Anderson, G. C., Holmes, K. W., & Sinnott, A. (2016). High soil sodicity and alkalinity cause transient salinity in south-western Australia. *Soil Research*, *54*(4), 407-417.

Bian, M., Jin, X., Broughton, S., Zhang, X.Q., Zhou, G., Zhou, M., Zhang, G., Sun, D. and Li, C., 2015. A new allele of acid soil tolerance gene from a malting barley variety. *BMC genetics*, *16*(1), p.1.

Borger, C.P., Riethmuller, G.P., Ashworth, M., Minkey, D. and Hashem, A., 2015. Carrier volume is more likely to impact trifluralin efficiency than crop residue. *Weed Technology*, *29*(1), pp.63–70.

Borger, C.P.D., Hashem, A. and Powles, S.B., 2016. Manipulating crop row orientation and crop density to suppress *Lolium rigidum*. *Weed Research*, *56*(1), pp.22–30.

Borger, C.P.D., Riethmuller, G. and D'Antuono, M., 2016. Eleven years of integrated weed management: long-term impacts of row spacing and harvest weed seed destruction on *Lolium rigidum* control. Weed Research, 56 (5) pp. 359–366.

Broughton, S., Zhou, G., Teakle, N.L., Matsuda, R., Zhou, M., O'Leary, R.A., Colmer, T.D. and Li, C., 2015. Waterlogging tolerance is associated with root porosity in barley (*Hordeum vulgare* L.). *Molecular Breeding*, *35*(1), pp.1–15.

Coutts, B.A., Cox, B.A., Thomas, G.J. and Jones, R.A.C., 2016. First report of Wheat mosaic virus infecting wheat in Western Australia. *Plant Disease*, *100*(2), pp.313–317.

David, J. M. (2015). Biochar and compost increase crop yields but the effect is short term on sandplain soils of Western Australia. *Pedosphere*, *25*(5), 720-728.

Fan, Y., Zhou, G., Shabala, S., Chen, Z.H., Cai, S., Li, C. and Zhou, M., 2016. Genome-wide association study reveals a new QTL for salinity tolerance in barley (*Hordeum vulgare* L.). *Frontiers in Plant Science*, *7*.

Ferguson, J.C., Chechetto, R.G., O'Donnell, C.C., Dorr, G.J., Moore, J.H., Baker, G.J., Powis, K.J. and Hewitt, .J., 2016. Determining the drift potential of Venturi nozzles compared with standard nozzles across three insecticide spray solutions in a wind tunnel. Pest Management Science, 72(8):1460-6.

French, R.J., Malik, R.S. and Seymour, M., 2015. Crop-sequence effects on productivity in a wheat-based cropping system at Wongan Hills, Western Australia. *Crop and Pasture Science*, *66*(6), pp.580–593.

French, R.J., Seymour, M. and Malik, R.S., 2016. Plant density response and optimum crop densities for canola (*Brassica napus* L.) in Western Australia. *Crop and Pasture Science*, *67*(4), pp.397–408.

Hall, D.J.M. and Bell, R.W., October 2015. Biochar and compost increase crop yields but the effect is short term on sandplain soils of Western Australia. Pedosphere, 25, pp. 720-728.

Hammond, N.E., Hardie, D., Hauser, C.E. and Reid, S.A., 2016. How would high priority pests be reported in the Western Australian grains industry? *Crop Protection*, *79*, pp.26–33.

Hammond, N.E.B., Hardie, D., Hauser, C.E. and Reid, S.A., 2016. Can general surveillance detect high priority pests in the Western Australian Grains Industry? *Crop Protection*, *79*, pp.8–14.

Harries, M., Anderson, G.C. and Hüberli, D., 2015. Crop sequences in Western Australia: what are they and are they sustainable? Findings of a four-year survey. *Crop and Pasture Science*, *66*(6), pp.634–647.

Hossain, M.M., Begum, M., Hashem, A., Rahman, M.M., Bell, R.W. and Haque, M.E., 2014. Yield response of mustard as influenced by weed management practice under conservation agriculture system. *Bangladesh J. Weed Sci*, *4*, pp.87-92.

Hua, W., Zhang, X.Q., Zhu, J., Shang, Y., Wang, J., Jia, Q., Zhang, Q., Yang, J. and Li, C., 2016. Identification and Fine Mapping of a White Husk Gene in Barley (*Hordeum vulgare* L.). *PloS one*, *11*(3), p.e0152128.

Hua, W., Zhang, X.Q., Zhu, J.H., Shang, Y., Wang, J.M., Jia, Q.J., Li, C.D. and Yang, J.M., 2015. A study of genetic diversity of colored barley (*Hordeum vulgare* L.) using SSR markers. *Genetic Resources and Crop Evolution, 62*, pp.395–406.

Huang, J., Barrett-Lennard, E. G., Kilminster, T., Sinnott, A., & Triantafilis, J. (2015). An error budget for mapping field-scale soil salinity at various depths using different sources of ancillary data. *Soil Science Society of America Journal*, *79*(6), 1717-1728.

Huang, Y., Cai, S., Ye, L., Han, Y., Wu, D., Dai, F., Li, C. and Zhang, G., 2014. Genetic architecture of limit dextrinase inhibitor (LDI) activity in Tibetan wild barley. *BMC plant biology*, *14*(1), p.1.

Huang, Y., Cai, S., Ye, L., Hu, H., Li, C. and Zhang, G., 2016. The effects of GA and ABA treatments on metabolite profile of germinating barley. *Food chemistry*, *192*, pp.928–933.

Jia, Q., Li, C., Shang, Y., Zhu, J., Hua, W., Wang, J., Yang, J. and Zhang, G., 2015. Molecular characterization and functional analysis of barley semi-dwarf mutant Riso no. 9265. *BMC genomics*, *16*(1), p.927.

Lawrenson, T., Shorinola, O., Stacey, N., Li, C., Østergaard, L., Patron, N., Uauy, C. and Harwood, W., 2015. Induction of targeted, heritable mutations in barley and *Brassica oleracea* using RNA-guided Cas9 nuclease. *Genome biology*, *16*(1), p.1.

Liu, L., Sun, G., Ren, X., Li, C. and Sun, D., 2015. Identification of QTL underlying physiological and morphological traits of flag leaf in barley. *BMC genetics*, *16*(1), p.1.

Ma, Q., Bell, R., Scanlan, C., Sarre, G., & Brennan, R. (2015). Growth and yield responses in wheat and barley to potassium supply under drought or moderately saline conditions in the south-west of Western Australia. *Crop and Pasture Science*, *66*(2), 135-144.

Ma, Y., Shabala, S., Li, C., Liu, C., Zhang, W. and Zhou, M., 2015. Quantitative Trait Loci for Salinity Tolerance Identified under Drained and Waterlogged Conditions and Their Association with Flowering Time in Barley (*Hordeum vulgare*. L). *PloS one*, *10*(8), p.e0134822.

Malik, R.S., Seymour, M., French, R.J., Kirkegaard, J.A., Lawes, R.A. and Liebig, M.A., 2015. Dynamic crop sequencing in Western Australian cropping systems. *Crop and Pasture Science*, *66*(6), pp.594–609.

Nansen, C., Ferguson, J.C., Moore, J., Groves, L., Emery, R., Garel, N. and Hewitt, A., 2015. Optimizing pesticide spray coverage using a novel web and smartphone tool, SnapCard. *Agronomy for Sustainable Development*, *35*(3), pp.1075–1085.

Nessa, B., Salam, M.U., Haque, A.M., Biswas, J.K., Kabir, M.S., MacLeod, W.J., D'Antuono, M., Barman, H.N., Latif, M.A. and Galloway, J., 2015. Spatial pattern of natural spread of rice false smut (*Ustilaginoidea virens*) disease in fields. *American Journal of Agricultural and Biological Sciences*, *10*(2), p.63.

Nessa, B., Salam, M.U., Haque, A.M., Biswas, J.K., Latif, M.A., Ali, M.A., Ansari, T.H., Ahmed, M., Parvin, N., Baki, M.Z.I. and Islam, S., 2016. Rice false smut disease at different flowering times. *Bangladesh Rice Journal*, *19*(2), pp.28–34.

Nessa, B., Salam, M.U., Haque, A.M., Biswas, J.K., MacLeod, W.J., Ali, M.A., Halder, K.P. and Galloway, J., 2015. FLYER: A simple yet robust model for estimating yield loss from rice false smut disease (Ustilaginoidea virens). *American Journal of Agricultural and Biological Sciences*, *10*(1), p.41.

Roper, M.M., Davies, S.L., Blackwell, P.S. and Ward, P.R., January 2015. Management options for water-repellent soils in Australian dryland agriculture. Soil Research, 53(7), pp. 786-806.

Rose, M.T., Cavagnaro, T.R., Scanlan, C.A., Rose, T.J., Vancov, T., Kimber, S., Kennedy, I.R., Kookana, R.S. and Van Zwieten, L., 2016. Impact of herbicides on soil biology and function. *Advances in Agronomy*, *136*, pp.133–220.

Sadeghzadeh, B., Rengel, Z. and Li, C., 2015. Quantitative Trait Loci (QTL) of Seed Zn Accumulation in Barley Population Clipper X Sahara. *Journal of Plant Nutrition*, *38*(11), pp.1672–1684.

Scanlan, C., Brennan, R. and Sarre, G.A., 2015. Effect of soil pH and crop sequence on the response of wheat (*Triticum aestivum*) to phosphorus fertiliser. *Crop and Pasture Science*, *66*(1), pp.23–31.

Scanlan, C.A., Bell, R.W. and Brennan, R.F., 2015. Simulating wheat growth response to potassium availability under field conditions in sandy soils. II. Effect of subsurface potassium on grain yield response to potassium fertiliser. *Field Crops Research*, *178*, pp.125–134.

Scanlan, C.A., Huth, N.I., Bell, R.W., 2015. Simulating wheat growth response to potassium availability under field conditions with sandy soils. I. Model development. *Field Crops Research, 178*, 109–124.

Setter, T. L., Waters, I., Stefanova, K., Munns, R., & Barrett-Lennard, E. G. (2016). Salt tolerance, date of flowering and rain affect the productivity of wheat and barley on rainfed saline land. *Field Crops Research*, *194*, 31-42.

Seymour, M., England, J.H., Malik, R., Rogers, D., Sutherland, A. and Randell, A., 2015. Effect of timing and height of defoliation on the grain yield of barley, wheat, oats and canola in Western Australia. *Crop and Pasture Science*, *66*(4), pp.287–300.

Seymour, M., Sprigg, S., French, B., Bucat, J., Malik, R. and Harries, M., 2016. Nitrogen responses of canola in low to medium rainfall environments of Western Australia. *Crop and Pasture Science*, *67*(4), pp.450–466.

Sudmeyer, R. A., & Hall, D. J. (2015). Competition for water between annual crops and short rotation mallee in dry climate agroforestry: The case for crop segregation rather than integration. *Biomass and Bioenergy*, *73*, 195-208.

Tucker, M.A., Moffat, C.S., Ellwood, S.R., Tan, K.C., Jayasena, K. and Oliver, R.P., 2015. Development of genetic SSR markers in *Blumeria graminis f. sp. hordei* and application to isolates from Australia. *Plant Pathology*, *64*(2), pp.337–343.

Wang, J., Yang, J., Zhang, Q., Zhu, J., Jia, Q., Hua, W., Shang, Y., Li, C. and Zhou, M., 2015. Mapping a major QTL for malt extract of barley from a cross between TX9425× Naso Nijo. *Theoretical and Applied Genetics*, *128*(5), pp.943–952.

Wang, X., Tang, C., Baldock, J.A., Butterly, C.R. and Gazey, C., 2016. Long-term effect of lime application on the chemical composition of soil organic carbon in acid soils varying in texture and liming history. *Biology and Fertility of Soils*, *52*(3), pp.295–306.

Yang, H., Jian, J., Li, X., Renshaw, D., Clements, J., Sweetingham, M.W., Tan, C. and Li, C., 2015. Application of whole genome re-sequencing data in the development of diagnostic DNA markers tightly linked to a disease-resistance locus for marker-assisted selection in lupin (*Lupinus angustifolius*). *BMC genomics*, *16*(1), p.1.

Yang, H., Li, C., Lam, H.M., Clements, J., Yan, G. and Zhao, S., 2015. Sequencing consolidates molecular markers with plant breeding practice. *Theoretical and Applied Genetics*, *128*(5), pp.779–795.

Ye, L., Huang, Y., Dai, F., Ning, H., Li, C., Zhou, M. and Zhang, G., 2015. Identification of two key genes controlling chill haze stability of beer in barley (*Hordeum vulgare* L). *BMC genomics*, *16*(1), p.1.

Zhang, H., Berger, J.D., Seymour, M., Brill, R., Herrmann, C., Quinlan, R. and Knell, G., 2016. Relative yield and profit of Australian hybrid compared with open-pollinated canola is largely determined by growing-season rainfall. *Crop and Pasture Science*, *67*(4), pp.323–331.

Zhang, Q., Zhang, X., Pettolino, F., Zhou, G. and Li, C., 2016. Changes in cell wall polysaccharide composition, gene transcription and alternative splicing in germinating barley embryos. *Journal of Plant Physiology*, *191*, pp.127–139.

Zhang, Q., Zhang, X., Wang, S., Tan, C., Zhou, G. and Li, C., 2016. Involvement of Alternative Splicing in Barley Seed Germination. *PloS one*, *11*(3), p.e0152824.

Zhang, X., Zhou, G., Shabala, S., Koutoulis, A., Shabala, L., Johnson, P., Li, C. and Zhou, M., 2016. Identification of aerenchyma formation-related QTL in barley that can be effective in breeding for waterlogging tolerance. *Theoretical and Applied Genetics*, *129*(6), pp.1167–1177.

Zhou, G., Broughton, S., Zhang, X.Q., Ma, Y., Zhou, M. and Li, C., 2016. Genome-Wide Association Mapping of Acid Soil Resistance in Barley (*Hordeum vulgare* L.). *Frontiers in plant science*, *7*.

Zhou, G., Panozzo, J., Zhang, X.Q., Cakir, M., Harasymow, S. and Li, C., 2016. QTL mapping reveals genetic architectures of malting quality between Australian and Canadian malting barley (*Hordeum vulgare* L.). *Molecular Breeding*, *36*(6), pp.1–12.

Zhou, G., Zhang, Q., Tan, C., Zhang, X.Q. and Li, C., 2015. Development of genome-wide InDel markers and their integration with SSR, DArT and SNP markers in single barley map. *BMC genomics*, *16*(1), p.1.

Zhou, G., Zhang, Q., Zhang, X.Q., Tan, C. and Li, C., 2015. Construction of high-density genetic map in barley through restriction-site associated DNA sequencing. *PloS one*, *10*(7), p.e0133161.

Books

Zhang, G. and Li, C., 2015. Exploration, identification and utilization of barley germplasm Academic Press, p. 304.

Book chapters

Angessa, T.T. and Li, C., 2015. Exploration and Utilization of Genetic Diversity Exotic Germplasm for Barley Improvement. *Exploration, Identification and Utilization of Barley Germplasm*, p. 223–238.

French, R.J., 2016. Field Pea: Agronomy. In: Wrigley, C., Corke, H. and Seetharaman, K., Faubion, J. (eds). Encyclopedia of Food Grains, 2nd Edition, pp. 240–250. Oxford: Academic Press.

Ma, Y., Zhou, M., Shabala, S. and Li, C., 2015. Exploration and Utilization of Waterlogging-Tolerant Barley Germplasm. *Exploration, Identification and Utilization of Barley Germplasm*, p.153–180.

Tucker, M.A., Lopez Ruiz, F., Jayasena, K. and Oliver, R.P., 2015. "Origin of fungicide resistance barley powdery mildew in West Australia – Lesson to be learned" Fungicide Resistance in Plant pathogens: Principals and a Guide to Practical Management. Springer, Japan. Chapter 20, pp.329–340.

Wrigley, C.W. and French, R.J., 2016. Grain Production and Consumption in Oceania: Australia and Pacific Countries. In: Wrigley, C., Corke, H. and Seetharaman, K., Faubion, J. (eds). Encyclopedia of Food Grains, 2nd edition Oxford: Academic Press. pp. 409-419.

Zhou, G., Zhou, M. and Li, C., 2016. Next-Generation Sequencing Technology: Implications for Barley Genetics and Breeding. *Exploration, Identification and Utilization of Barley Germplasm*, pp.265–280.

Conference papers

Brunton, D.J., Dhammu, H.S., Wheeler, R.D., Kelly, A., Bell, K., Lockley, P., Churchett, J. and Walker, S., 2015. Interaction of Genotype, Environment and Herbicides in wheat (*Triticum aestivuum* L.) and barley (*Hordeum vulgare* L.) across a range of environments in Australia. In Proceedings of the 17th ASA Conference, 20–24 September 2015, Hobart, Australia. www.agronomy2015.com.au

Ferguson, J.C., O'Donnell, C.C., Moore, J.H., Chauhan, B.S., Adkins, S.W., Kruger, G.R., Chechetto, R.G. and Hewitt, A.J., 2015. Improving canopy penetration in cereals and canola: What have we learned through our intensive 2-year study in Australia? In Proceedings of the 70th Annual Meeting of the North Central Weed Science Society. Indianapolis, December 7-10. Indianapolis: Curran Associates. 70.

Gazey, C (2015). Lime and P. In Fertilizer 2015. Mandurah, Septmeber 30 2015. Australia: Fertilizer Australia. http://www.fertilizer.org.au/Publications-and-Events/Conference-Proceedings-2015-Mandurah.

Hossain, M.M., Begum, M., Hashem, A., Rahman, M.M., Bell, R.W. and Haque, M.E., 2015. Yield response of transplanted aman rice to weed management practice under conservation agriculture system. S.V.R. Shetty *et al*. (Eds) Proceeding of the 25th Asia Pacific Weed Science Society conference held in India (September 2015), pp.615.

Jayasena, K., Anikster, Y., Eilam, T. and Ezrati, S., 2015. Understanding the barley leaf rust new pathotype 5457 P- in Western Australia Australasian Plant Pathology Society Conference, 14–16 September 2015, Fremantle, Western Australia, pp.142.

Jayasena, K., Thomas, G., Tanaka, K., Wahlsten, L. and Lambert, V., 2015. Interaction of fungicide and genetic resistance for the management of barley leaf rust. Australasian Plant Pathology Society Conference, 14–16 September 2015, Fremantle, Western Australia, pp.141.

Nessa, B., Salam, M.U., Haque, A.H.M.M., Biswas JK, M. Latif MA, Ali MA, Ansari TH, Jahan QSA, Khan MAI, Bhuiyan MR, Ahmed, M., Ara, M.A., Parvin, N. and Galloway, J., 2016. Pattern of ball development on panicles in relation to rice false smut disease. In proceedings of 9th Biennial Conference of the Bangladesh Phytopathology Society, Bangladesh Agricultural Research Institute (BARI), 18 February 2016. p. 3.

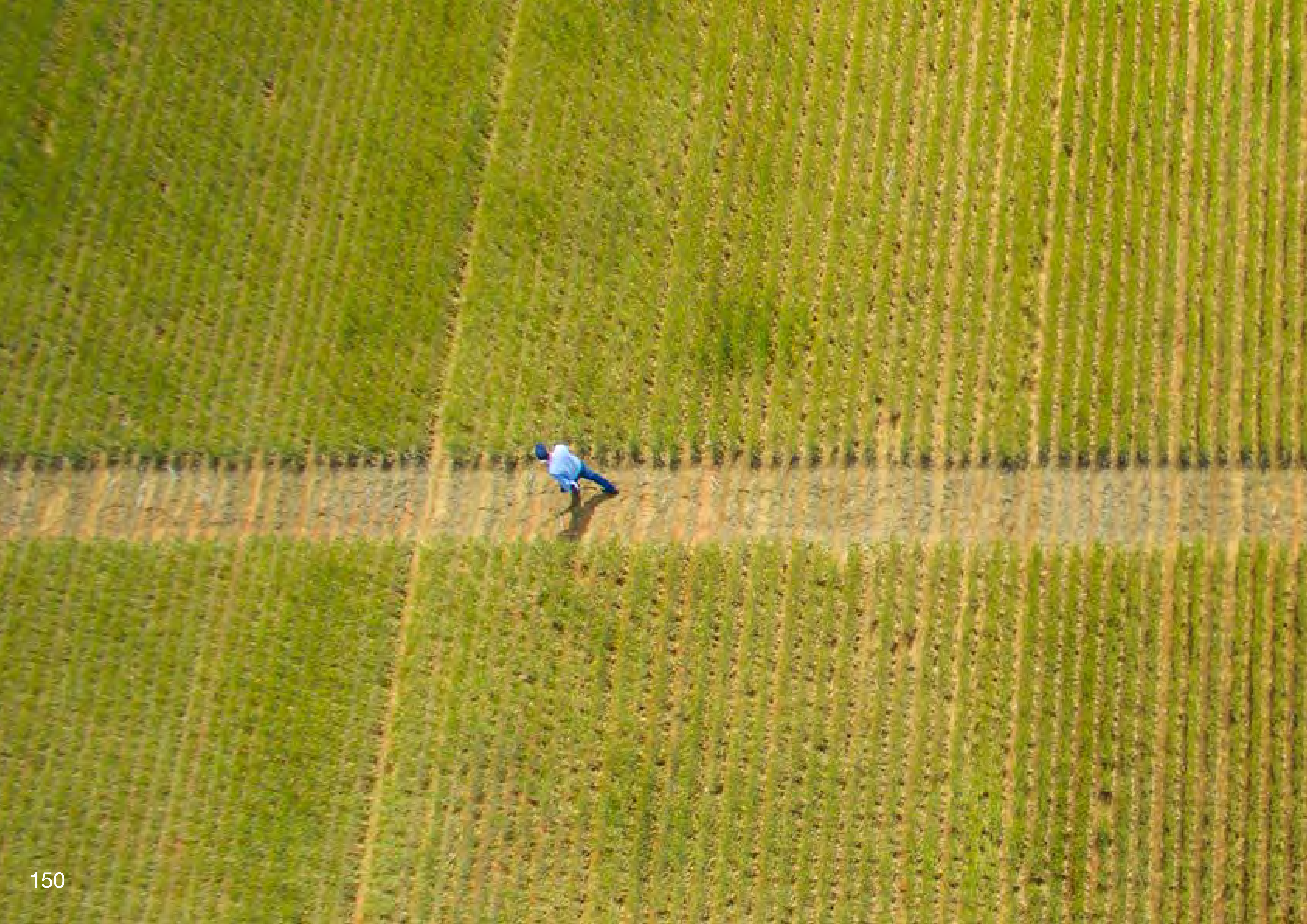
Nessa, B., Salam, M.U., Haque, A.H.M.M., Biswas, J.K., Latif, M.A., Ali, M.A. and Galloway, J., 2016. Rice false smut disease at different time of transplanting, on ratoons and tolerance to genotypes. In proceedings of 9th Biennial Conference of the Bangladesh Phytopathology Society, Bangladesh Agricultural Research Institute (BARI), 18 February 2016.p.4

Scanlan, C.A., Brennan, R.F., D'Antuono, M.F., Sarre, G.A., 2015. Lime and P: The full story, In Fertiliser 2015. Mandurah, September 30 2015. Australia: Fertilizer Australia. http://www.fertilizer.org.au/Publications-and-Events/Conference-Proceedings-2015-Mandurah.

Zhang, H., Berger, J. D., Seymour, M., Brill, R., Quinlan, R. and Knell, G., 2015. The response of hybrid and open-pollinated canola to the environment in southern Australia. "Building Productive, Diverse and Sustainable Landscapes" Proceedings of the 17th ASA Conference, 20–24 September 2015, Hobart, Australia, pp 67-70.

Annual Grains Research Updates

Research papers have been prepared for Grains Research Updates (formerly Agribusiness Crop Updates) over the lifespan of the event. These papers can be found on the Grains Industry Association of Western Australia web page at giwa.org.au



GOVERNMENT OF
WESTERN AUSTRALIA

Department of
Agriculture and **Food**

enquiries@agric.wa.gov.au

South Perth head office
Phone: +61 (0)8 9368 3333
Fax: +61 (0)8 9474 2405

Address: 3 Baron-Hay Court South
Perth WA 6151
Postal: Locked Bag 4 Bentley Delivery
Centre WA 6983

agric.wa.gov.au