GOONDIWINDI
QLD
WEDNESDAY 28
JULY 2022

GRAINS RESEARCH UPDATE

DRIVING PROFIT THROUGH RESEARCH

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GRDC 2022 Grains Research Update Welcome

Welcome to the first of our northern GRDC Grains Research Updates for 2022.

For the last two years, we've had to alter plans to host these updates virtually but thanks to the easing of COVID-19 pandemic restrictions, we're finally able to have everyone back to listen to our research, development and extension (RD&E) updates in person.

The northern region has had its fair share of challenges this year. While seasonal conditions have improved and provided reprieve for growers, advisers, agronomists and researchers, parts of New South Wales and Queensland have had to battle the implications of excessive rainfall and wet conditions.

Untimely rain has forced many growers to alter their operations and look at how they can do things differently to work with the wet conditions. Despite the difficulties, feedback from growers has still been optimistic with most supporting the notion of there being more money in mud than dust.

With that positive mindset comes a need to provide the latest information and advice from grains research and development. There's also been a significant push from the industry to make more informed management decisions to ensure productivity isn't impacted by the increasing costs of inputs.

We would like to take this opportunity to thank our many research partners who have gone above and beyond normal expectation this season to extend the significant outcomes their work has achieved to growers and advisers.

For more than a quarter of a century the GRDC has been driving grains research capability and capacity with the understanding that high quality, effective RD&E is vital to the continued viability of the industry.

Sharing the results from this research is a key role of the annual GRDC Updates, which bring together some of Australia's leading grains research scientists and expert consultants. We trust they will help guide your on-farm decisions this season and into the future.

To ensure this research answers the most pressing profitability and productivity questions from the paddock, it is critical the GRDC is engaged with and listening to growers, agronomists and advisers. To this end, GRDC has established the National Grower Network Forums and I encourage you to look out for these forum opportunities in your local area.

GRDC has also placed significant importance on having staff in the regions – whether it be travelling to events like this or being based in our regional offices across the country, including Toowoomba and Wagga Wagga.

We feel more connected to the industry than ever when we are out in the regions and encourage you all to take any opportunity to engage with us to help inform our important RD&E portfolio.

If you have concerns, questions or feedback please contact our team directly (details on the back of these proceedings) or email northern@grdc.com.au.

Regards,
Gillian Meppem
Senior Regional Manager – North

GOONDIWINDI
GRDC Grains Research Update
Thursday 28 July 2022

Goondiwindi Community Centre, Cnr Russell & Short Streets, Goondiwindi

Registration: 8:30am for a 9am start, finish 2:40pm

AGENDA		
Time	**Topic**	**Speaker(s)**
9:00 AM	**GRDC welcome**	
9:10 AM	**An inversion drift hazard alert and warning system for eastern Australia -** advantages of 24-hour monitoring & forecasts	Graeme Tepper (Micrometeorological Research)
9:40 AM	**Grain storage** • Managing chickpea and cereal quality in on-farm storage • New data on falling numbers • Storage environment, variety & harvest conditions, and aeration performance & back pressures	Chris Warrick (Primary Business)
10:10 AM	**Cereal disease issues with rusts and yellow leaf spot in 2022**	Lislé Snyman (DAF Qld)
10:35 AM	**MORNING TEA**	
11:05 AM	**Crown-rot management -** pushing wheat rotations, variety tolerance vs resistance, basal browning vs yield impact, stripper front impacts	Steve Simpfendorfer (NSW DPI)
11:35 AM	**How well does canola fit into northern farming systems?**	Lindsay Bell (CSIRO)
12:05 PM	**Optimising sorghum production in NNSW & southern Qld**	Loretta Serafin (NSW DPI)
12:35 PM	**LUNCH**	
1:35 PM	**Managing problem summer grass weeds with pre-emergents**	Richard Daniel (Northern Grower Alliance)
2:05 PM	**P dynamics in vertosols -** what factors influence how long deep P lasts for & what impact the application method and subsequent tillage have	Mike Bell (UQ)
2:40 PM	**CLOSE**	

Contents

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Spray drift hazard warning system

Graeme Tepper, MicroMeteorological Research and Educational Services

Key words

drift, inversions, hazardous, warning, forecasts, towers and network

GRDC code

MRE00002 & CRDC code: MRES2101

Take home message

Utilising real time and forecast guidance of hazardous inversion spray conditions for your local region from a drift hazard warning system, will negate the need for guesswork as the prime input into critical spray decisions. This should lead to significant reductions in drift events. Less drift will reduce the loss of valuable crop protection products and associated off target damage to sensitive areas and crops.

Spray drift hazard warning system

The spray drift hazard warning system is a new and leading-edge technology developed in Australia, for Australian conditions. It offers detailed real time information of environmental conditions impacting spray operations and the dispersion of potential drift. It replaces inadequate and antiquated guesswork and the visual cues currently relied on to determine critical spray conditions, including the presence of hazardous temperature inversions. While the system delivers around the clock information, a key benefit is to provide support to those growers wishing to spray during night hours. When fully functional, it will enable for more efficient night-time spraying through identification of hazardous conditions in real time. The network also provides a 24-hour forecast, broken into 2-hourly intervals, significantly helping growers and applicators to plan the logistics of spray operations.

Spray drift still impacts many industries, the environment and human health

Spray drift represents as loss of product and a potential reduction in efficacy at the application target site. While direct drift can have an obvious source i.e., when damage occurs downwind from the application site, widespread drift damage having no visible gradients is most likely caused by the release of a component of the spray volume with droplet sizes small enough to allow for its continued suspension and movement in localised laminar air streams. These drift incidences, commonly associated with hazardous temperature inversion conditions, are caused by a lack of atmospheric turbulence to effectively disperse these suspended spray particles.

Under hazardous inversion conditions, spray particles may remain suspended for long periods of time, allowing for the particles from single or multiple application points to combine into much higher concentrations before deposition. Higher concentrations lead to greater impacts regardless of the susceptibility of affected off target crops and plants. Spray drift can negatively impact crops, flora, fauna, waterways and human health. It can cause harm to Australian exports and impact the future availability of valuable crop protection products.

Some recent examples of impactful drift:

- The sudden defoliation of hundreds of plants west of Dubbo has raised fresh concerns about chemical spray drift from local cotton farms and stoked tensions between landowners and aerial operators (2021)

- In 2018, while less than 10% of the Australian cotton crop was reported as impacted by spray drift, the financial impact was significant - costing an estimated **$18 million in production losses**
- In 2016 an estimated 26% of the cotton crop was affected by spray drift (Source: Cotton Australia)
- Sorghum crops on the Darling Downs and Central Queensland have been impacted
- Vineyards in the Riverland and Clare Valley have suffered
- Almond farms in the Mallee have been damaged.

Even coarse spray quality can drift

Bill Gordon found that:

- "With a coarse spray quality, drift may travel 300 to 400 meters **by day** (*and further- but difficult to detect*)
- **Spraying at night** using the same products, nozzles and ground speed can leave up to 5 times more chemical in the air. Resulting in spray drifting 10 to 20 kilometers or more at night
- This is unacceptable for other farmers, the community and the environment."

Spraying at night when hazardous inversion conditions exist

- Will lead to the highest possible concentrations (sometimes combinations from multiple applications across thousands of hectares) of pesticides floating and spreading horizontally
- Spray drift is caught up in local winds transporting it at between 2 and 11 kph; sometimes more.

Current regulations permitting pesticide application

- DO NOT apply if there is hazardous surface temperature inversion conditions present at the application site during the time of application
- When application occurs in an area not covered by recognised inversion monitoring weather stations, all surface temperature inversion conditions must be regarded as hazardous.
- For full details please see the APVMA website at https://apvma.gov.au/node/10796

Definitions of 'hazardous' and 'recognised inversion monitoring'

Based on research of Grace and Tepper 2022:

- Hazardous inversions occur when the atmosphere is strongly stable and the intensity of turbulence is so weak that drift is not dispersed vertically
- Recognised monitoring systems have sensors to measure the intensity of vertical turbulence.
- Refer to spray drift definitions at APVMA website at https://apvma.gov.au/node/51381

Warning system infrastructure and layout

The network coverage of 100, 10 m high, Profiling Automatic Weathers Stations (PAWS) to be established before the summer of 2022/23 is depicted below (Figure 1).

Deliverables

The system will support more informed decision making. It will:

- Provide applicators with real time data indicating the presence or absence of hazardous inversion conditions
- Deliver short term forecasts up to24 hours, segmented into 2-hour blocks, to assist in planning and optimal utilisation of human and machine resources.

System benefits

Currently, the vast majority of growers rely on guesswork and limited visual cues, to determine if hazardous inversions exist. Decisions based on these tenuous clues are fraught with uncertainty, false detections and missed events.

Use of the system will:

- Replace guesswork as the main support for critical decision making
- Provide real time data updated every 10 minutes
- 24-hour short-term forecasting in support of planning and logistics
- Provide less skilled labour clear indications of when to GO/STOP
- Archived data will provide in-depth local knowledge of typical conditions and trends to be expected by month and season
- In-depth knowledge will support improved deployment of manpower and equipment
- Provide all the standard weather data at greater granularity then currently available
- Deliver data to current and future automatic spray systems.

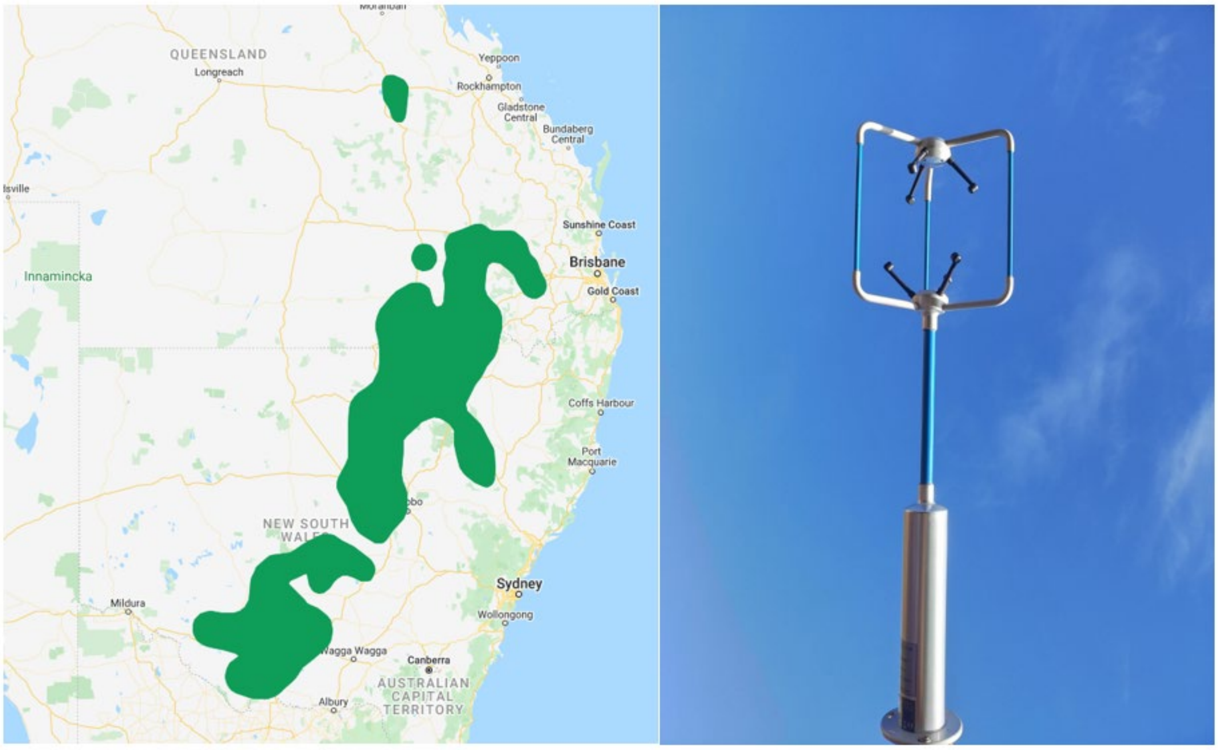

Figure 1. System coverage and the turbulence and wind sensor.

Figure 2. System infrastructure.

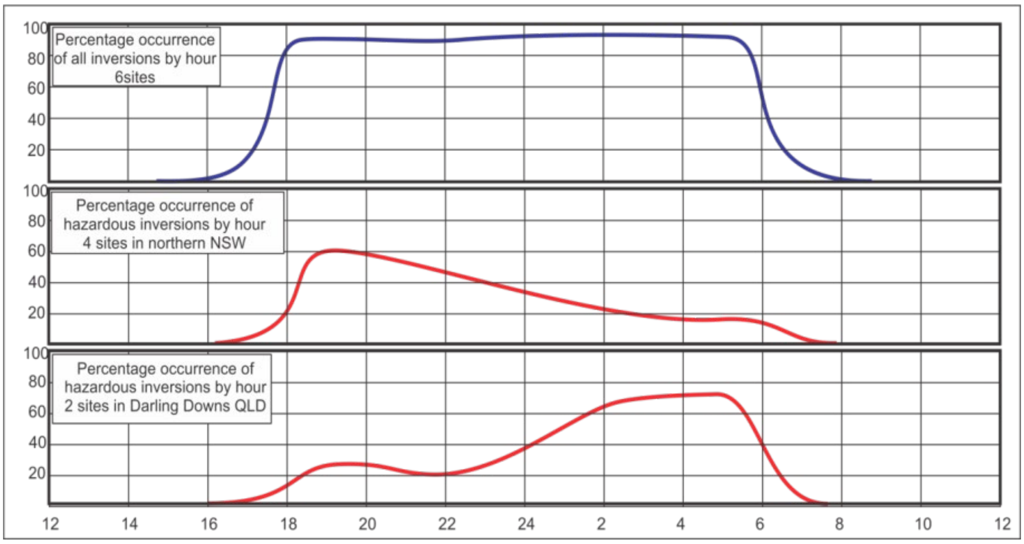

Figure 3. In some regions hazardous inversions are most frequent in the early evening. Percent of inversion occurrence by hour (top 'at 6 sites', middle 'at 4 sites in NNSW' and bottom 'at 2 sites on the Darling Downs')

A grower trial of the spray drift hazard warning system indicated that its use leads to:

- Spraying longer in optimal conditions
- Avoidance of hazardous conditions.

Growers found that the flow on effects of utilizing the system were:

- Improved practices and efficiencies:

    - in the timing of applications, and
    - improved allocation of manpower/machine (operating hours operators did not sit around waiting for good conditions).

Common response from users: The system was a real eye opener. They learnt a lot.

Future potential

The system will differentiate between hazardous and non-hazardous inversions and increase spray hours.

Data and advice could potentially be integrated into automated sprayer systems.

Acknowledgements

The research undertaken was made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, CRDC, and DPIRD. The author would like to thank them for their valued support.

GRDC funded - Management of spray drift through inversion risk awareness- supported and managed by DAFWA- DAW 00231 - 01/07/2013 to 30/06/2016). GRDC - Air inversion modelling to manage spray drift, MRE00002; 01/02/2016 to 30/06/2019 with 3 extensions through to 2022.

CRDC funded - Development of a Spray Drift Hazard prediction system, MRES 2101, 1/07/2016 to 30/06/2019: and Spray decision systems and resources grower testing, MRES 2001, 15/02/2020 to 11/06/2020.

References

Research methods and outcomes are published in the Journal of Applied Meteorology and Climatology. https://journals.ametsoc.org/view/journals/apme/apme-overview.xml

Micrometeorological Aspects of Spraying within a Surface Inversion by Warwick Grace and Graeme Tepper 2021. https://journals.ametsoc.org/search?f_0=author&q_0=Graeme+Tepper

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Managing grain quality during storage

Chris Warrick, Primary Business

Key words

grain storage, aeration, falling number, back pressure, grain quality, temperature, moisture

GRDC code

PRB2011-001SAX

Take home messages

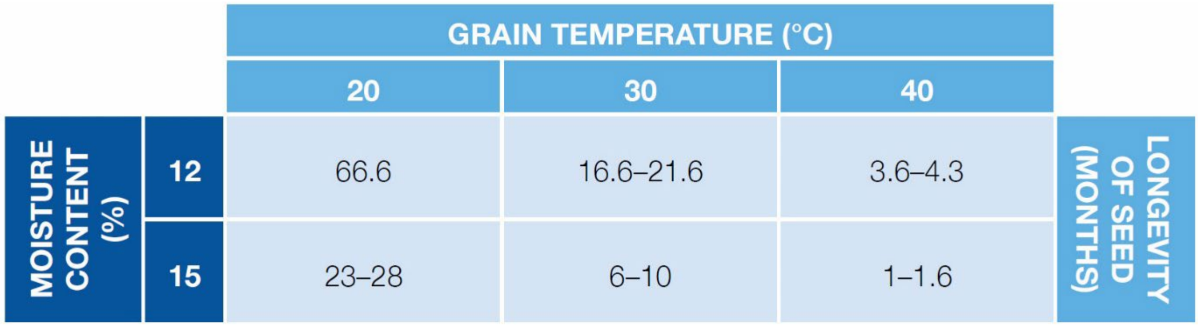
- Aeration cooling can help in a wet harvest but can't replicate drying – understand aeration capacity
- Cool and dry storage conditions maintain chickpea seed viability significantly longer than warm, moist conditions
- Falling numbers could possibly improve after harvest – watch this space for research results.

Aeration

Until recently, aeration systems have relied on American research from 1951 to model fan performance requirements to overcome the backpressure of various types of grain at varying depths. In 2022 highly accurate pressure and airflow meters combined with an investment from the GRDC has enabled research to determine the backpressure and therefore fan performance required to aerate Australia's commonly grown grains at typical storage depths.

Aeration is designed to achieve one of two main functions – cooling or drying. Understanding the difference is the first step, understanding the system requirements is the next, and of course then learning how to operate and manage storages with aeration cooling or drying is what makes it a valuable tool.

Existing Pulse Australia research tells us that chickpea seed longevity is sustained for significantly longer when stored in cool, dry conditions. Take for example chickpea harvested at 40 degrees Celsius and 15 per cent moisture content without aeration cooing, will have an expected seed life of 1 to 1.6 months. Compare that to chickpeas stored at 20 degrees Celsius and 12 per cent moisture content having a seed life in excess of 66 months.



		GRAIN TEMPERATURE (°C)			
		20	30	40	
MOISTURE CONTENT (%)	12	66.6	16.6–21.6	3.6–4.3	LONGEVITY OF SEED (MONTHS)
	15	23–28	6–10	1–1.6	

Source: Pulse Australia

Figure 1. Storage life of chickpeas (months)

Research currently being undertaken in Horsham by Agriculture Victoria is also indicating grain colour, in particular in pulses can be maintained for longer in cooler storage conditions, i.e., with aeration cooling.

Cooling grain to maintain grain quality, prevent mould and deter or slow insect activity requires 2-4 litres of air per second per tonne of grain. To dry grain with aeration, flowrates have to be over 15 l/s/t to reliably carry moisture out of the grain bulk. Understanding that a one per cent drop in moisture content equates to 10 L of water per tonne, or 1000 L of water from 100 t and the requirement for high airflows for drying make sense.

While the flow rates used for aeration cooling won't dry grain, it can even grain moisture within a grain bulk to aid blending and prevent mould from developing around green grains or clusters of higher moisture grain. Aeration cooing can even be used to hold over moisture grain for a few months until it can be blended or dried. Anecdotally, growers are utilising aeration cooling to hold over moisture grain allowing harvest to start sooner, or earlier each day, then blending with low moisture grain harvested later in the season or in the afternoons.

The 2022 GRDC research revealed that aeration backpressure increases exponentially with grain depth and air flowrate. Aeration cooling in canola requires a fan that can perform against nearly two and a half times the backpressure of wheat in a ten-metre-high storage. In contrast, aeration cooling chickpeas requires a fan to work against only one quarter the of backpressure of wheat in a 10m high storage.

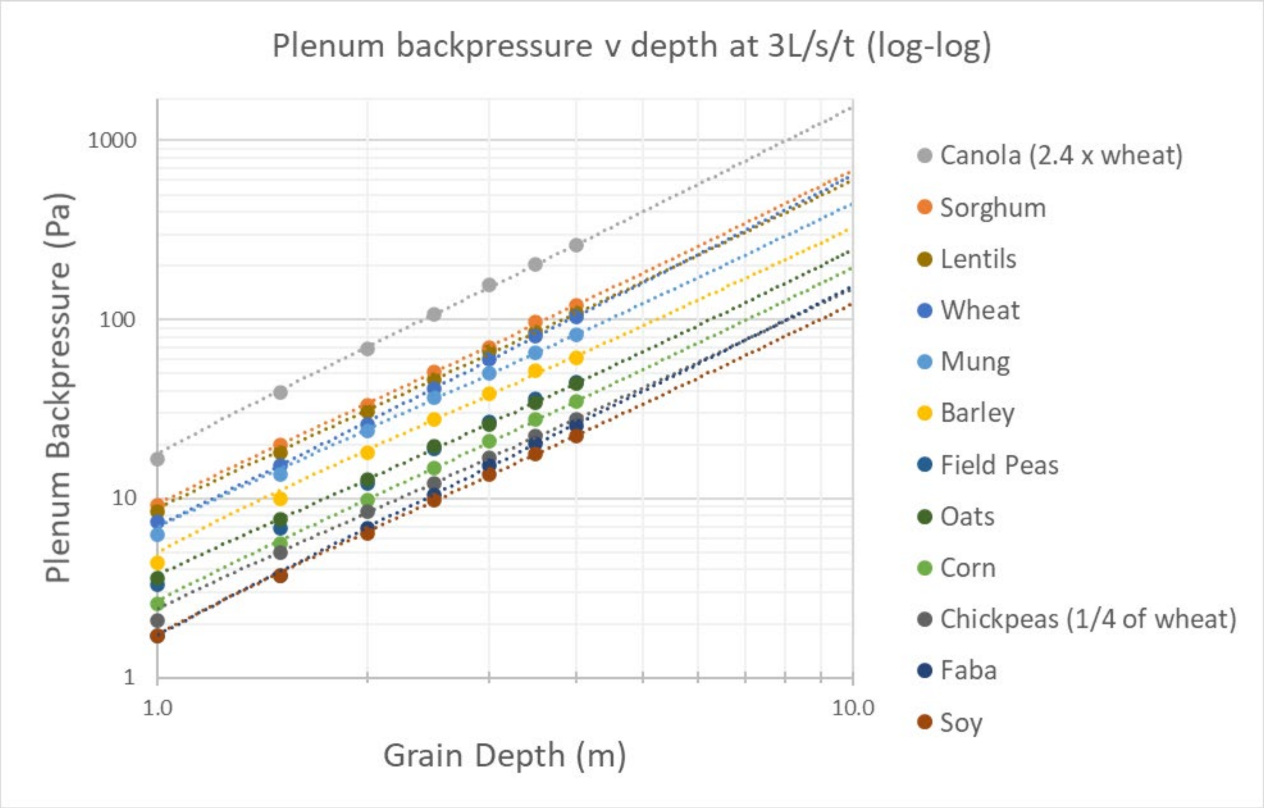


Figure 2. Aeration cooling backpressure by grain type (Source: GRDC)

Matching fans to storages require a decision of the main function – cooling or drying, then of what grain types and to what depth. For most growers, storages are used for many grain types so the most efficient system may require variable speed fans, or multiple fans that can be turned on or off as required. It's worth noting that multiple fans have to overcome the back pressure of each other before the backpressure of the grain, so doubling the number of fans may increase the air flow, but will not double the air flow.

Falling numbers after harvest

Anecdotally, some growers have reported improved falling number test results on weather damaged grain after it has been held in storage. Unable to find any reliable laboratory or field research, the GRDC swiftly commissioned research in 2022 to test the observation.

The aim of the research is to answer initial questions in a short space of time with the opportunity of weather damaged grain from 2021. The main question being, can falling number test results be improved with time in storage?

Secondary questions are, if possible, how far could we expect test results to improve, how long does it take, does grain storage temperature and moisture influence results and are there varietal differences? If proven possible, further research may be required to test the effect on milling and malting quality of weather damaged grain if its falling number test has been improved with time in storage.

Stay tuned for results to be released via the GRDC communication channels and storedgrain.com.au later in 2022.

Acknowledgements

GRDC Grain Storage Extension Project. Ben White, Philip Burrill, Alex Conway, Jo Panozzo, Felicity Harris

The research undertaken as part of this project is made possible by the significant contributions of growers and supply chain businesses through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

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Managing rust and yellow leaf spot in 2022

Lislé Snyman, Dept. Agriculture and Fisheries Queensland

Key words

barley, wheat, stripe rust, leaf rust, yellow leaf spot, varieties, management

GRDC codes

National Variety Disease Screening (NVT)

UOA2003-008: Program 2: Minimising the impact of major barley foliar pathogens on yield and profit – surveillance and monitoring of pathogen populations.

DAQ2106-007: Disease surveillance and related diagnostics for the Australian grains industry within the northern region

Take home messages

- Management strategies for foliar diseases include resistant varieties, crop rotation, seed treatment and timely fungicide application
- Monitor crops for early disease detection
- Crop rotation and reducing surface stubble decrease inoculum levels of stubble-borne diseases
- Limit fungicide application by spraying only when necessary, rotate fungicides with different modes of action and use recommended rates
- Economic response to fungicide application is a factor of varietal susceptibility, severity of the epidemic, product choice and application timing.

Background – 2022 season

La Nina has impacted farming operations in many Queensland cereal growing regions with above average monthly rainfall since November 2021. In many areas planting is/has been delayed and many early sown crops are waterlogged. The Hermitage Research station has received 650mm of rain since January 2022, surpassing the long term annual mean rainfall (Fig. 1).

Wet and humid conditions are favourable for disease development; hence diseases are expected to have a major impact on production in 2022. Disease management will be crucial to limit yield and quality loss.

An increase in rust observations were made in wheat and barley crops in Qld. in 2021. This could be attributed to a return of environmental conditions favourable for disease development. Ninety-two rust samples collected in Qld. were submitted to the Plant Breeding Institute (PBI), Sydney University for pathotyping. These include leaf rust samples collected from both wheat (6) and barley (9) and 58 wheat stripe rust samples. A significant stripe rust epidemic was reported in NSW in 2021 (Simpfendorfer et al 2022). Despite an increase in rust observations in Qld. in 2021, dry conditions during August and September limited disease spread and impact.

Wet conditions over summer provided an opportunity for rusts to survive and be present at higher levels than what we were used to in recent years, early in the growing season. These pathogens have the ability to develop into epidemics very quickly if conditions are suitable. Current environmental conditions will likely result in rust epidemics in 2022.

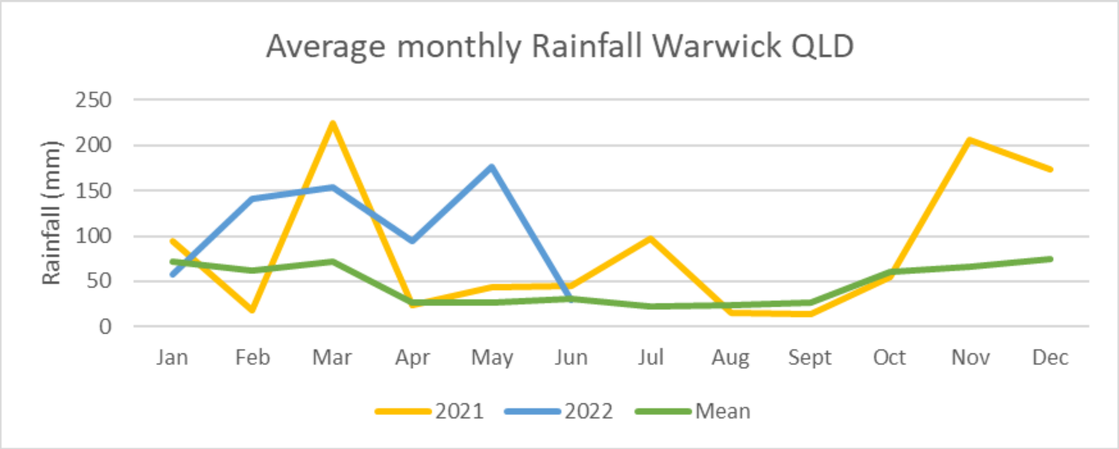

Figure 1. Monthly rainfall for the Hermitage Research Station, Warwick.
(Note June 2022 rainfall as of 20 June)

Barley leaf rust

Leaf rust of barley is widely distributed and occurs regularly in the northern region. It is considered one of the five major barley diseases in Australia and can significantly reduce yield and quality. Barley leaf rust was widespread in Queensland in 2016, but due to the drought conditions, was only present at very low levels until 2021. Samples submitted from Qld crops during 2021 to PBI, were collected from varieties Compassᶲ, Laperouseᶲ and Leabrookᶲ. These varieties are rated as susceptible to very susceptible (SVS) in Qld. We can expect these varieties to be planted across Qld growing regions in 2022, with increased acreage expected to be planted to the new varieties Yetiᶲ (SVS) and Beastᶲ (S).

The disease is caused by the obligate parasite, *Puccinia hordei.* It spreads by means of airborne spores, able to travel long distances. The pathogen spreads rapidly when conditions are favourable and large areas are planted to susceptible varieties, resulting in the development of epidemics. In the presence of a green bridge, the pathogen can survive over summer and be present at high levels early in the growing season. High inoculum levels put pressure on major resistance genes and can lead to the development of new, more virulent pathotypes.

Large areas sown to S to VS varieties across a range of environments almost ensures that leaf rust will be a problem in some areas, contributing to high inoculum levels causing epidemics whilst adding selection pressure on the pathogen to mutate and acquire new virulences.

Wheat rusts – stripe rust

The stripe rust situation in Eastern Australia has changed dramatically since 2020. Of main concern are two recent exotic incursions, the 239 E237 A- 17+ 33+ and the 198 E16 A+ J+ T+ 17+ pathotypes (pts).

The 239 pt. was identified in Victoria in 2017 and despite not being detected in 2018 and 2019, was widespread in NSW in 2020. Many varieties are vulnerable to this pathotype.

The 198 pt. was first detected in SNSW in 2018 and spread quickly from there across Eastern Australia. It was the dominant pt. in 2020 and has an impact on many varieties, including some durum and triticale varieties.

These two pts are very different and vary in their impact on varieties. Some varieties are more susceptible to the 239 pt. than the 198 pt. Varieties such as Rockstarᶲ, Vixenᶲ and Catapultᶲ did well in 2020, but not so much in 2021 due to the increase in the 239 pathotype and their vulnerability to that particular pt. Varietal responses are determined by the distribution and spread of these pathotypes; both pathotypes were detected across Qld. growing regions in 2021. Responses of Australian wheat varieties to these pathotypes are available in Cereal Rust Report Vol 17(3) (Park et al, 2020).

Wheat rusts – leaf rust

As with stripe rust, there has been some changes in the leaf rust landscape with a couple of exotic introductions and a new pt. developing locally. They are not expected to be an additional threat to current varieties, but could increase rust on varieties carrying *Lr24.* Growers are advised to monitor crops of varieties carrying *Lr24*. Some of the more widely planted varieties in southern Queensland that rely on the LR24 gene include; Bremerⓟ , Chief CL Plusⓟ , Cutlassⓟ , Elmore CL Plusⓟ , Impress CL Plusⓟ , LRPB Gazelleⓟ , LRPB Lancerⓟ , LRPB Oryxⓟ , LRPB Parakeetⓟ , Sunchaserⓟ and Sunguardⓟ. Varietal responses to leaf rust are also reported in Cereal Rust Report 18(2).

Wheat yellow spot

Yellow spot is a stubble-borne fungal disease caused by the pathogen *Pyrenophora tritici-repentis* and reduces yield and quality. Yield loss depends on varietal resistance and severity of the disease.

Symptoms include tan-coloured oval lesions becoming darker in the centre with a yellow margin, often observed in young seedling leaves from where the disease moves up the plant under suitable conditions. As lesions merge and coalesce, they produce large areas of necrotic tissue, causing leaf death and reducing photosynthetic area.

The fungus survives as small, black fruiting bodies on stubble. From there, fungal spores are released after rain events and spread onto nearby seedlings, resulting in primary infection. Secondary spread occurs when asexual spores are produced on leaves and dispersed by wind, infecting new leaves and neighbouring crops.

At least six hours of leaf wetness with temperatures of 15-28°C are required for the successful infection of leaves from stubble. Secondary infection (leaf to leaf) is favoured by leaf wetness, high humidity and optimum temperatures between 15°C and 25°C.

Disease management

Foliar pathogens are a significant challenge to the grains industry and a major constraint to profitable winter cereal production, affecting both yield and quality. Many of these pathogens are genetically and pathogenically diverse, able to reproduce sexually and can rapidly develop new virulence's and overcome genetic resistance.

Growing a high yielding, well adapted, resistant variety provides the most economic and environmentally friendly means of disease control. Genetic resistances need to be durable to provide long-term protection.

Successful management of yellow spot requires an integrated disease management approach including crop rotation (i.e., avoid wheat on wheat), timely application of fungicides to protect the money leaves (flag and flag-1), removal of stubble and using resistant varieties. A much greater proportion of our wheat cropping area is sown to varieties with useful levels of resistance to yellow spot than a decade ago; therefore, it is worthwhile to consider the economics of fungicide application in relation to varietal resistance and epidemic potential before spraying. Stubble of susceptible varieties harbours more inoculum, hence avoid sowing a susceptible variety into stubble from a previously infected susceptible crop at all cost.

In susceptible varieties where yield potential is high, fungicidal control can be justified. Foliar fungicides should be aimed at protecting the key leaves present during grain filling – namely, the flag leaf sheath, the flag leaf (f), flag-1 (f-1), and f-2.

To ensure that fungicides remain effective, it is important to limit fungicide application by spraying only, when necessary, rotate fungicides with different modes of action and use fungicides at recommended rates. Fungicide applications are more effective if applied before disease becomes established in the crop. This requires regular monitoring to ensure crops can be sprayed at the first sign of disease. When conditions are favourable for disease development, more frequent crop inspections will be needed and repeat fungicide applications may be necessary.

Conclusion and 2022 planning

The absence and/or low incidence of many diseases in 2021 in the northern region does not mean that we can get complacent. With favourable environmental conditions, pathogens will continue to cause yield and quality loss and we have to make the right decisions to ensure that we can stay ahead of disease development and the evolution of the pathogen.

Current and forecast weather conditions indicate that disease epidemics are likely in 2022. Monitoring of crops will play a crucial role in disease management this season.

Continuous monitoring of pathogen populations provides information on the virulence’s present and the spread of pathogens. Submit samples of rust to the University of Sydney Australian Cereal Rust Survey and samples of net form net blotch to DAF for pathotyping.

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The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

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Is there a disease downside to stripper fronts?
Harvest height implications for Fusarium crown rot management

*Toni Petronaitis[1,2], Clayton Forknall[3], Steven Simpfendorfer[1], Richard Flavel[2]
and David Backhouse[2]*

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Key words

cereal stubble, stubble management, integrated disease management, Kelly-chain, post-harvest, chickpea, wheat, barley

GRDC codes

DAN00213: Grains Agronomy & Pathology Partnership (GAPP) - A strategic partnership between GRDC and NSW DPI. Projects BLG211 and BLG304 GAPP PhD
DAQ00208 – Statistics for the Australian Grains Industry – North

Take home messages

- Taller standing stubble allowed vertical progression of the Fusarium crown rot fungus within the stubble after harvest, whilst short stubble prevented further growth (i.e. vertical growth was limited to the height of the cut stubble).
- Stripper fronts, which leave higher standing stubble, may increase stubble-borne disease inoculum after harvest of an infected crop, especially if wet fallow conditions are experienced.
- In high-risk situations, such as an infected crop with high biomass, cutting the crop shorter at harvest will limit further inoculum development within the stubble after harvest (beyond the levels already present at harvest).
- Cutting infected cereal stubble shorter prior to rotation with shorter-stature crops such as chickpea or lentils also prevents the dispersal of infected stubble when harvesting these shorter break crops.

Introduction

Despite continuous research and the development of crop protection strategies, the impacts of Fusarium crown rot (FCR), caused by the fungus *Fusarium pseudograminearum* (*Fp*), have increased in Australia over the past four decades. The adoption of conservation-agriculture practices such as cereal stubble retention helps to offset the risk of low in-crop rainfall but promotes the carry-over of *Fp* inoculum to successive cereal crops (Simpfendorfer and McKay, 2019). Despite the yield penalties associated with FCR, the benefits of cereal stubble retention on soil structure, moisture and fertility are considered a necessity in the northern grain's region (NGR, northern New South Wales and Queensland). Finding ways to limit the negative effects of disease whilst retaining cereal stubble is therefore important to crop production in the NGR.

The adoption of higher harvest-heights (stripper-fronts), light tillage (Kelly-chaining) and rotations with shorter stature break crops such as chickpea (*Cicer arietinum*) are becoming common in the NGR. Stripper front harvesting systems improve harvest efficiency through the rapid 'stripping' of heads during harvest, but also increases retained standing stubble biomass by increasing standing stubble height i.e., ~50-60 cm compared to ~30 cm with a combine harvester. It is unknown how such an increase in vertical cereal stubble height will affect the survival and/or growth of *Fp*.

Fusarium pseudograminearum is capable of surviving in post-harvest cereal stubble for ~3 years (Summerell and Burgess 1988) and can also continue to colonise (grow) in post-harvest cereal stubble (Petronaitis *et al.* 2020) by a process known as saprotrophic colonisation. Additional cereal stubble remaining from stripper front-harvests may increase the opportunity for saprotrophic colonisation, as there is more cereal stubble to vertically colonise, compared to the extent of growth possible in stubble remaining from conventional or shorter harvest-heights. This has the potential to increase inoculum levels and inoculum dispersal. As such, lowering of the harvest-height of a cereal crop infected with *Fp* may restrict saprotrophic colonisation of standing cereal stubble after harvest. If true, reducing or modifying harvest-heights of cereals infected with FCR could be beneficial for preventing further increases in *Fp* inoculum levels during fallow or non-host periods.

What did we do?

Field experiments were conducted at Breeza and Narrabri in northern New South Wales, spanning the 2019, 2020 and 2021 winter crop growing seasons. Cereal stubble (from durum wheat of the variety DBA Lillaroiᶲ) with extensive *Fp* colonisation was established at both sites in 2019 and a range of target harvest-height (low, medium or high) and harvest-trash (trash returned to plot or trash removed off plot) treatments were imposed at harvest in 2019. Prior to sowing in 2020, an additional stubble management treatment (Kelly-chain) was imposed on a selection of plots. This treatment was applied in combination with the harvest-height treatments, to plots that had previously had trash retained. A chickpea break crop (PBA Seamerᶲ) was subsequently sown across both field experiments in 2020.

Chickpea plant populations (plants/m^2) of variety PBA Seamerᶲ were counted in each plot 30 days after planting. Lowest pod heights were measured on two random plants per plot prior to harvest as the distance from ground level to lowest pod. Grain yield was determined from machine harvested grain samples taken from 2 × 10 m plots.

Soil moisture content (SMC) was measured in November 2019, May 2020 and November 2020. One 1.2 metre soil core was sampled per plot and cut into 0-30 cm, 30-60 cm, 60-90 cm and 90-120 cm segments. The wet weight and dry (dried for 48 hours at 105 °C) weight of each soil segment was measured to calculate gravimetric SMC.

Durum stubble from 30 plants were collected at random across each plot in November 2019 (durum harvest), May 2020 (chickpea sowing) and November 2020 (chickpea harvest). Stubble was separated into individual tillers and twenty tillers were then selected randomly for culturing. Starting at the stem base (crown), a 1.5 cm segment was removed from the tiller every 5 cm along the entire tiller length. Stem portions were surface sterilised (5 mL sodium hypochlorite solution, 45 mL deionised water, 50 mL >98% ethanol) for 1 minute then washed with sterile water. Samples were dried overnight and plated on 1/4 strength potato dextrose agar (PDA) + novobiocin (10 g PDA, 15 g technical agar plus 0.1 g novobiocin/L water) and incubated under alternating ultra-violet light (12 h light/12 h dark) for 7 days at 25 °C. Pathogen incidence was recorded as the number of segments producing typical *Fp* colonies based on morphology. Maximum colonisation was defined as the maximum height at which *Fp* was detected in each sample.

The nine stubble management treatments (factorial combination of harvest-height and harvest-trash, plus Kelly-chain treatments), were randomly assigned to plots in each experiment according to a randomised block design, with three replicate blocks. The response variable, length of maximum colonisation, was analysed across sampling times, for each experiment separately using a linear mixed model framework, whereby treatments, sampling time and their interaction were fit as fixed effects while structural terms were fit as random. The analysis of SMC used a similar modelling approach with the treatment structure expanded to include a fixed effect corresponding to the depth of sampling, and the subsequent interaction effects between depth, treatments and sampling time. Response variables related to chickpea crop performance were analysed separately for each experiment. All models were fit using the ASReml-R package in the R statistical computing environment.

What did we find?

Saprotrophic colonisation of cereal stubble by Fp was restricted in shorter stubble

The maximum colonisation height of *Fp* in the post-harvest cereal stubble increased significantly over the 2019-20 fallow in the medium (32 or 25 cm) and tall (48 or 38 cm) stubble at both sites ($P < 0.001$, Figure 1). *Fp* height did not change in the short (17 or 13 cm) stubble because the fungus had already reached the observed (cut) height at harvest (Nov 2019). At Breeza, maximum colonisation height increased significantly in medium (+11.1 cm) and tall (+22.2 cm) stubble over the fallow period from Nov 2019 to May 2020 (Figure 1). Similarly, at Narrabri, *Fp* progressed significantly in medium (+15.2 cm) and tall (+21.4 cm) stubble over the same period (Figure 1). Maximum colonisation then decreased slightly over the chickpea break crop period (from May 2020 to Nov 2020) but was still elevated significantly in the medium and tall stubble compared with the shorter stubble heights at both sites (Figure 1).

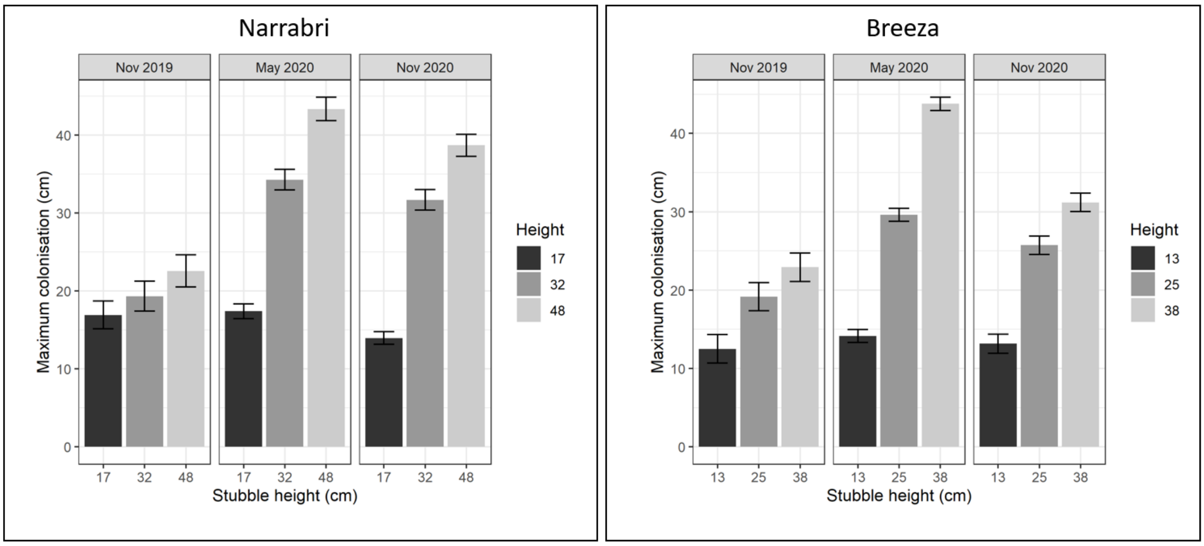

Figure 1. Maximum vertical colonisation by *Fusarium pseudograminearum* in cereal stubble of different heights (mean observed height, in cm) from harvest of the infected crop (Nov 2019), a summer fallow (May 2020) and a chickpea break crop (Nov 2020) at Breeza and Narrabri in NSW. Note harvest-heights were unique to each site due to differences in final crop height in 2019, with slight variability in actual height achieved between and across plots for each target height treatment. Error bars represent the approximate back-transformed standard error of the mean.

Maximum colonisation of short stubble at Breeza in November 2019 was significantly lower than medium and tall stubble, but this was possibly a reflection of the shorter stubble treatment imposed (stubble was sampled after harvest), given that maximum colonisation at the Narrabri site was more uniform (Figure 1). Maximum colonisation measurements above the mean observed height (e.g., Breeza in May 2020), was due to variation in individual tiller lengths within a harvest-height treatment (Figure 1). There was no effect of cereal trash treatment (retained, removed or Kelly-chained) on maximum colonisation at each time of sampling for both sites ($P > 0.1$).

These results demonstrate that *Fp* can continue to saprotrophically colonise cereal stubble after harvest. Specifically, if stubble is left longer, *Fp* can colonise to the cut height of cereal stubble in the first six months after harvest and persist high within the stem for at least another six months (compared with levels at harvest in November 2019). These findings support the concept that lower cereal harvest-heights are effective at preventing the vertical progression of *Fp* in infected standing stubble post-harvest.

Cereal stubble treatments did not compromise soil moisture

There were no detrimental effects of the cereal stubble treatments on soil moisture levels after the 2019 summer fallow (May 2020) and after harvest of the chickpea crop (November 2020) ($P > 0.2$) (data not shown). There was good fallow rainfall at both sites: 324 mm at Narrabri and 439 mm at Breeza (from 01/12/19 to 31/05/20), significantly increasing soil moisture over the fallow period (for depths 0 to 90 cm, $P < 0.03$). So although the stubble treatments didn't affect fallow efficiency at these sites, the different stubble treatments may have had a more profound impact on soil moisture levels if drier conditions had persisted over summer and autumn.

Chickpea crop performance was not affected by cereal stubble treatments

Overall, the cereal stubble treatments did not have any meaningful impact on chickpea performance in these experiments, with no differences in yield, and only minor differences in chickpea establishment. There was no significant effect on chickpea yield of standing stubble height ($P > 0.96$), trash treatment ($P > 0.19$) or the interaction of harvest-height and trash treatments ($P > 0.14$) at both sites (data not shown). At Breeza, the Kelly-chained treatment resulted in slightly higher chickpea establishment (+4 plants per m^2) compared to the trash retained treatment ($P = 0.05$), possibly due to better seed-soil contact when using a disc seeder in Kelly-chained plots. Lowest pod height was not affected by cereal stubble treatments at either site ($P > 0.32$).

Implications for stripper front harvest adoption

The present study confirms that *Fp* can saprotrophically colonise the full length of cereal stubble in the field, given sufficient fallow rainfall. Harvesting higher with a stripper front may therefore increase risk of higher *Fp* inoculum levels compared harvesting at a lower height with a conventional combine header. Given that *Fp* is detected in 100% of cereal crops in New South Wales (with majority in the 'high' category) (Milgate and Simpfendorfer, 2020), the widespread use of stripper fronts could result in further increases in disease incidence and severity in this region. Planning for stubble management (including stubble/harvest heights) prior to harvest, based on the infection status of the cereal crop to be harvested and future crop sequence, is therefore recommended.

In cereal crops infected with *Fp*, reducing stubble height by harvesting lower would be a useful strategy to limit saprotrophic colonisation after harvest. Ideally, harvest height would be above the height at which the stubble has already been colonised by *Fp*, as this means that less infected stubble is spread into the inter-row spaces, thus optimising inter-row sowing strategies to minimise disease in subsequent cereal crops. This approach could still be used with stripper-fronts by stripping grain, if desired, then following up with a shorter harvest height. The cut fraction (free of pathogen) could be left between rows as mulch or baled and removed. If saprotrophic colonisation has occurred during a wet summer period, cutting low, baling and removing the infected stubble prior to sowing the next crop is preferred to burning stubble. This way there is still a proportion of ground cover to protect the soil surface, but the bulk of inoculum that may infect the next crop has been removed.

Restricting movement of *Fp* vertically within standing cereal stubble may provide two-fold benefits. Firstly, it can prevent inoculum build-up within the standing stubble fraction, beyond the inoculum levels present at harvest. Secondly, it may stop the spread of inoculum across a paddock during harvest of short-stature crops such as chickpea, improving the efficacy of inoculum avoidance strategies like inter-row sowing. Harvesting cereals above the height of *Fp* colonisation could prevent the non-colonised stubble fraction from becoming saprotrophically colonised. Although the cereal harvest-height modification for FCR management appears promising, the implications on FCR risk in a subsequent cereal crop are still to be determined in these field experiments in 2021 (results not available at time of writing).

Stripper fronts offer faster and more efficient crop harvest but could potentially create future issues in cereal crops infected with *Fp*. Even if only low levels of infection are experienced during the growing season, or disease expression is restricted (stem browning/whiteheads) by favourable seasonal conditions or plant tolerance, rapid colonisation of stubble may still occur after plant senescence (Petronaitis *et al*. 2020). So, be vigilant about checking your cereal crops for disease symptoms and consider confirmation of inoculum levels and hence risk through diagnostic services if necessary.

Testing using PREDICTA® B is effective in determining disease risk (following the up-to-date protocol of adding cereal stubble to the sample). If your paddock/s have returned a below detection limit or low risk PREDICTA® B test for cereal disease, then you can continue following best practise agronomy for your next cereal crop.

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Fusarium crown rot seed fungicides: independent field evaluation 2018-2021

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Keywords

fungicide seed treatments, yield loss, wheat, barley, durum, disease

GRDC codes

DAN00213: Grains Agronomy & Pathology Partnership (GAPP) - A strategic partnership between GRDC and NSW DPI (Project BLG208) and DAN00175: National crown rot epidemiology and management program.

Take home messages

- Current fungicide seed treatments registered for the suppression of Fusarium crown rot (FCR) inconsistently reduce the extent of yield loss from FCR
- Victrato® had consistent and stronger activity on limiting yield loss from FCR
- However, under high infection levels, significant yield loss may still occur in drier seasons
- Fungicide seed treatments, including Victrato®, should not be considered standalone control options for FCR
- Seed treatments should be used as an additional tool within existing integrated disease management strategies for FCR.

Introduction

Fusarium crown rot (FCR), caused predominantly by the fungal pathogen *Fusarium pseudograminearum* (*Fp*), is a major constraint to winter cereal production across Australia. A range of integrated management strategies including crop rotation, varietal selection, inter-row sowing, sowing time, stubble and fallow management are required to minimise losses. A number of fungicide seed treatments have been registered for the suppression of FCR in recent years with a further product Victrato® from Syngenta likely to be available to Australian growers prior to sowing in 2024. Although chemical companies conduct their own widespread field evaluation across Australia, growers and their advisers value independent evaluation of the potential relative fit of these fungicide seed treatments within integrated management strategies for FCR.

What we did

A total of 15 replicated plot experiments (generally 2 x 10 m with minimum of 3 replicates) were conducted across NSW from 2018-2021 with one additional field experiment conducted in Victoria (Horsham) and two in WA (Merredin and Wongan Hills) in 2018 only (Table 1). The winter cereal crop and number of varieties differed between experiments with wheat (W), barley (B) and/or durum (D) evaluated in each experiment (Table 1).

Six fungicide seed treatments: Nil, Vibrance® (difenoconazole + metalaxyl-M + sedaxane at 360 mL/ 100 kg seed), Rancona® Dimension (ipconazole + metalaxyl at 320 mL/100 kg seed), EverGol®Energy (prothioconazole + metalaxyl + penflufen at 260 mL/100 kg seed) and Victrato® (Tymirium™ technology based on cyclobutrifluram at 40 and/or 80 g active ingredient/100 kg seed). All fungicide seed treatments were applied in 1 to 3 kg batches using a small seed treating unit to ensure good even coverage of seed. Note that not all six seed treatments were examined in 2020 and 2021.

All field experiments used an inoculated vs uninoculated randomised complete block design with inoculated plots infected by *Fp* inoculum grown on sterilised wheat grain added at 2.0 g/m of row at sowing. This ensures high (>80%) FCR infection in inoculated plots with uninoculated plots only exposed to background levels of *Fp* inoculum naturally present across a site. This design allows comparison between the yield effects of the various fungicide seed treatments in the presence and absence (background levels) of FCR. Yield loss from this disease is measured as the difference between inoculated and uninoculated treatments.

What did we find?

Averaged across all cereal entries

Lower levels of in-crop rainfall between March and September generally lowered the yield potential at each site in each season, but also increased the extent of FCR yield loss. This was highlighted in the nil seed treatments where yield loss ranged from 11 to 48% in 2018, 14 to 20% in 2019, 11 to 37% in 2020 and 9 to 11% in 2021 (Table 1).

Table 1. Effect of various fungicide seed treatments on yield loss (%) associated with Fusarium crown rot infection in 18 replicated inoculated vs uninoculated field experiments – 2018 to 2021

Year	**Location**	**Crop[A]**	**Rainfall[B] (mm)**	**Yield[c] (t/ha)**	**%Yield loss from Fusarium crown rot[D]**					
					Nil	**Vibrance**	**Rancona Dimension**	**EverGol Energy**	**Victrato 40 gai[E]**	**Victrato 80 gai[E]**
2018	Merriwagga, NSW	2W	63	1.44	44	nd[F]	nd	32	25	18
	Mallowa, NSW	2W	73	1.73	48	nd	nd	nd	26	24
	Gilgandra, NSW	2W	93	2.14	42	35	27	28	16	9
	Merredin, WA	2W	182	2.66	35	nd	nd	nd	23	13
	Horsham, Vic	2W	185	2.56	21	nd	nd	nd	+2[I]	+5
	Wongan Hills, WA	2W	291	3.27	11	nd	nd	nd	1	0
2019	Gulargambone, NSW	W/B	141	3.12	20	2	5	9	-[G]	+2
	Narrabri, NSW	W/B	200[H]	4.01	14	10	9	7	-[G]	6
2020	Boomi, NSW	3W/D	202	4.91	37	nd	28	nd	24	18
	Gurley, NSW	W/B	234	6.50	13	nd	nd	nd	-[G]	1
	Rowena, NSW	W/B	247	6.21	12	7	nd	4	-[G]	2
	Trangie, NSW	3W/D	412	4.13	26	20	23	19	4	2
	Gilgandra, NSW	3W/D	420	4.07	12	6	7	7	3	0
	Armatree, NSW	3W/D	425	4.37	11	nd	nd	7	3	+1
2021	Boomi, NSW	3W/D	349	5.74	10	-[G]	-[G]	-[G]	2	+1
	Armatree, NSW	3W/D	404	6.67	11	-[G]	-[G]	-[G]	2	1
	Wongarbon, NSW	3W/D	424	5.68	9	-[G]	-[G]	-[G]	6	4
	Rowena, NSW	3W/D	454	6.80	11	-[G]	-[G]	-[G]	1	0

[A] Winter crop type variety numbers where W = wheat variety, B = barley variety and D = durum variety.

[B] Rainfall in-crop from March to September at each site. Critical time for fungicide uptake off seed and expression of FCR.

[C] Yield in uninoculated treatment (average of varieties) with nil seed treatment.

[D] Average percentage yield loss from FCR for each seed treatment (averaged across varieties) compared with the uninoculated/nil seed treatment.

[E] gai = grams of active ingredient.

[F] nd = no difference, %yield loss from FCR with fungicide seed treatment not significantly different from the nil seed treatment. . Values only presented when reduction in %yield loss from FCR significantly lower than the nil seed treatment.

[G] All treatments not included at these sites.

[H] Included two irrigations at GS30 and GS39 of 40 mm and 30 mm respectively due to drought conditions.

[I] Results with a plus in front of them show that the treatment yielded higher than the uninoculated nil treatment (i.e. the treatment reduced impact from both the added FCR inoculum as well as natural background levels of fusarium present at that site.

Vibrance and Rancona Dimension significantly reduced the extent of yield loss from FCR in 6 of 14 experiments whilst EverGol Energy reduced FCR yield loss in 8 of 14 field trials (Table 1). However, the Victrato significantly reduced yield loss from FCR in 14 of 14 trials at the 40 gai rate and 18 of 18 field experiments at the 80 gai rate (Table 1). The reduction in yield loss was also generally stronger with this product compared with the other fungicide seed treatments and better at the 80 gai than 40 gai rate (Table 1).

Significant yield loss (9 to 26%) still occurred with Victrato at drier sites. These dry conditions increased the yield loss from FCR (>35% in nil seed treatment). However, the 80 gai rate at these disease conducive sites, at least halved the yield loss compared with the nil seed treatment (Table 1). Yield loss from FCR was lower at the wetter sites (<26%). Victrato reduced yield loss to <6%, with increased yields at some sites due the effects of background levels of FCR infection being reduced (Table 1). Moisture stress during grain filling exacerbates yield loss from FCR and favours the growth of *Fp* within the base of infected plants. Dry soil conditions throughout the season at the seeding depth, is likely to restrict the movement of fungicide actives off the seed coat and into surrounding soil and uptake by root systems. This would reduce movement of the fungicides into the sub-crown internode, crown and tiller bases where FCR infection is concentrated. It is currently not clear if reduced efficacy under drier conditions may be related to one or both of these factors.

What about durum?

Durum wheat is known to have increased susceptibility to FCR compared with many wheat and barley varieties. The increased prevalence of FCR in farming systems aided by the adoption of conservation cropping practices, including retention of cereal stubble, has seen durum removed from rotations due to this risk. The durum variety DBA Lillaroi⦶ was compared with three bread wheat varieties at four sites in 2020 (Table 1).

Table 2. Effect of Victrato seed treatment at two rates on the extent of yield loss[A] (%) from Fusarium crown rot in three bread wheat (W) and one durum (D) variety at three sites in 2020

Variety	Boomi 2020			Trangie 2020			Gilgandra 2020			Armatree 2020		
	Nil[B]	Victrato 40 gai	Victrato 80 gai	Nil	Victrato 40 gai	Victrato 80 gai	Nil	Victrato 40 gai	Victrato 80 gai	Nil	Victrato 40 gai	Victrato 80 gai
Lancer⦶ (W)	29	23	20	30	10	8	13	2	0	9	4	+7[C]
Mitch⦶ (W)	39	18	11	13	+2	+5	9	2	1	5	0	0
Trojan⦶ (W)	34	22	18	20	4	2	12	1	0	14	2	2
Lillaroi⦶ (D)	48	32	24	45	11	6	16	5	+2	14	6	+2

[A] Average percentage yield loss from FCR for each seed treatment compared with the uninoculated/nil seed treatment for that variety.

[B] Nil = no seed treatment.

[C] Results with a plus in front of them show that the treatment yielded higher than the uninoculated nil treatment (i.e. the treatment reduced impact from both the added FCR inoculum as well as natural background levels of fusarium present at that site.

The extent of yield loss from FCR with nil seed treatment was generally higher in the durum variety (14 to 48%) compared with the three bread wheat varieties (5 to 39%). The bread wheat variety Mitch⦶ tended to have reduced yield loss from FCR compared with the other entries, apart from the Boomi site (Table 2). Yield loss from FCR was reduced with Victrato in both the bread wheat and durum varieties (Table 2). Even in the higher loss site at Boomi in 2020, the 80 gai rate halved the extent of yield loss in the durum variety Lillaroi⦶ with better efficacy in the other three sites.

Conclusions

Current fungicide seed treatments registered for the suppression of FCR can inconsistently reduce the extent of yield loss from this disease. Victrato appears to have more consistent and stronger activity on limiting FCR yield loss. In the absence of fungicide seed treatments, average yield loss from FCR infection across the 18 sites over three seasons was 21.5%. The 80 gai rate of Victrato significantly reduced the level of yield loss from FCR down to an average of 4.9% across these 18 field experiments. Under high infection levels, as created with artificial inoculation in these experiments, significant yield loss may still occur (up to 24% measured), particularly in drier seasons.

Dry soil conditions around the seeding depth throughout a season may reduce the uptake of fungicides applied to the seed coat. Drier seasons also exacerbate FCR expression, which would place additional pressure on fungicide seed treatments. However, even under these conditions Victrato at the 80 gai rate still at least halved the level of yield loss from FCR.

Fungicide seed treatments, including Victrato, should not be considered standalone control options for FCR. Rather, they should be used as an additional tool within existing integrated disease management strategies for FCR.

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How well does canola fit into northern farming systems?

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Key words

canola, soil water, nitrogen, rotation, risk, disease, root lesion nematodes

GRDC codes

DAQ2007-002RTX, CSP00187, CSA00050, DAQ00192

Take home messages

- Canola offers a range of rotational benefits for disease management, weed management, and the potential to widen sowing windows
- Understand when canola would most likely fit into your system to maximise its benefits and mitigate its risks – that is, when you should put it in your mix of crop choices
- Farming system data shows significant opportunities for canola, but risks are still significant
- Canola won't suit all situations – several aspects need to line up to mitigate risk and maximise benefits. Critical aspects to consider include:
    - Soil water at sowing – threshold of > 150 mm in most locations to mitigate risk of low crop yields
    - Sowing window – understand your optimal sowing window to manage the risk of frost and heat stress during critical periods
    - Disease or weed issues – use canola where you are going to reap the benefits in subsequent years (e.g., winter grass problems, high *Pratylenchus thornei* nematode populations)
    - Ensure sufficient N is available – avoid situations with low starting soil N, as this will be difficult to address in northern systems with applied fertilisers at sowing or in season.
    - Preceding crops – be cautious of crops that host sclerotinia which increases disease risk (e.g., chickpea)
    - Following crops – use canola leading into disease-sensitive crops/varieties, N availability is likely to be a little higher than after cereals, consider following with another break crop, i.e., a 'double-break' to 'reset' the system.

Introduction

Northern farming systems are challenged by a lack of reliable break crops that offer effective weed management options and help with reducing soil-borne diseases such as nematodes, Fusarium crown rot, and charcoal rot. Canola is one winter crop option that provides these benefits. Canola is a highly profitable staple crop in southern farming systems and a range of historical work has explored the wider potential of expanding its use further north (see Holland et al. 2001, Robertson et al. 2004). However, canola has traditionally been perceived as a risky crop in northern farming systems due to the greater frequency of high/low temperatures during grain filling, which often result in significant yield, quality and oil content downgrades.

Despite this history, there is now a wide range of varieties that fit a diverse range of niches in the farming system, ranging in phenology (or growing season length) to fit different sowing windows, and herbicide tolerance packages. Alongside improved planting equipment with better depth control, these advances address some of the limitations to using canola more widely in northern grain systems.

Recent research in the 'Optimising Canola Profitability' project has established a range of extension material to help guide the management of canola crops in the north, covering; crop planning and preparation, matching varieties with sowing dates, crop protection, nutrition, and harvest management (see 20 Tips for profitable Canola). The paper compliments this information by addressing the questions; 1) Is it worth it – what is the opportunity vs the risk? 2) When and how would it fit into my system? 3) What are the likely legacy impacts I need to consider?

Crop reliability & risk mitigation

Sowing opportunities & establishment

As canola has relatively small seed that must be planted shallow (<40mm depth), this limits the duration of the sowing window to plant into surface moisture. The reliability and frequency of suitable sowing events in the right window for canola can be a critical constraint to incorporating it more reliably into northern farming systems. Below (Figure 1) we compare the frequency that a sowing event is likely to occur in different fortnightly windows through autumn at a selection of locations. A sowing event is defined as a rainfall event exceeding potential evaporation over a 7-day period. This shows that in more temperate, winter dominant rainfall locations where canola is widely used (e.g., Young), a sowing opportunity occurs during mid-April to mid-May in over 70% of years. In contrast, in northern NSW and southern Qld, with less and more variable autumn rainfall, the frequency of this sowing event is significantly lower at around 40-50% of years. Whilst this is likely to limit the frequency that canola could be effectively established in the north, it does show that in around half the years we are likely to still receive conditions that should allow canola to be sown in a viable window. This also shows that at many of our locations there are often sowing opportunities in early April (about 1-in-4 to 1-in-5 years), which may allow longer season canola cultivars to be used.

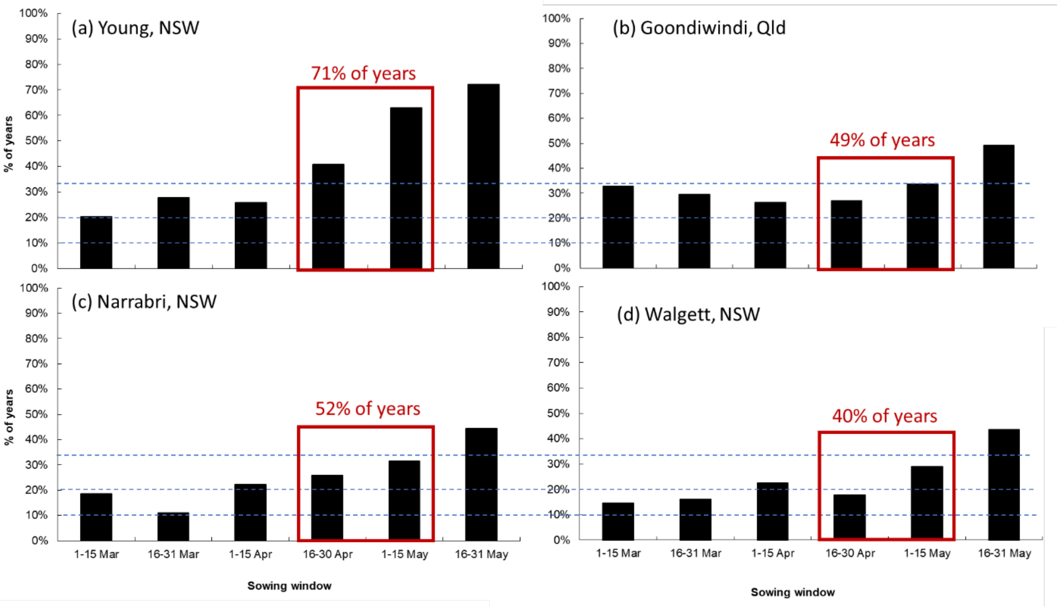

Figure 1. Historical (1956-2015) analysis of frequency of a sowing event (i.e. rainfall exceeding evaporation over 7 day period) across fortnightly sowing windows comparing a southern NSW site (Young) with 3 northern locations. The red box depicts the optimal canola sowing window in late April and early May and the total frequency that such an event occurs in this period.

Crop yields and soil water use

As part of the northern farming systems research sites over the past 6 years, canola has been grown on 9 unique occasions across southern Qld, central NSW, and northern NSW under a diversity of seasonal conditions (see Table 1). This provides a useful snapshot of what might be expected for canola performance in the northern region. From these sites, 3 of the 10 site-seasons achieved low yields (<0.5 t/ha), which were attributable to a frost event during early pod-fill (Narrabri 2017) and very dry conditions after sowing in 2019, when less than 200 mm of water (as rain or stored water) was available to the crop throughout the season. Five of the 9 site-seasons achieved grain yields of 2.5-3.5 t/ha, which occurred under conditions where the crop had access to over 350mm of water during the season. Most of these crops started with soil profiles >60% full prior to reaching the sowing window, which contributed around 30% of the water used by the crop. This was augmented by additional in-crop rain at around the long-term average winter season rainfall across these locations (i.e., 200-300mm) except for Trangie in 2020 on a Red soil with a low plant available water content (PAWC), these high yielding crops all started with >150 mm of PAW prior to sowing. The harvest index (0.23-0.27) and grain water use efficiency (WUE) (≤ 8.0) measured in these studies were less than those that are typically expected in more traditional canola-growing regions.

Table 1. Canola crop productivity (grain yield and biomass produced) & water used across farming systems experiments conducted 2015-2021.

Site-Year	Year	Yield (t/ha)	Biomass (t/ha)	Harvest Index	Water used (mm)	Pre-sow PAW (mm)	Biomass WUE (kg DM/mm)	Grain WUE (kg DM/mm)
NARRABRI	**2017**	0^{A}	8.0	0	320	146	25	0
NOWLEY	**2019**	0.21	1.9	0.10	183	53	10	1.1
TRANGIE RED	**2019**	0.44	1.8	0.25	139	22	13	3.2
BILLA BILLA	**2018**	1.46	6.0	0.24	255	114	24	5.7
TRANGIE GRAY	**2020**	2.70	13.6	0.20	403	148	34	6.7
TRANGIE RED	**2020**	2.94	10.8	0.27	371	63	29	7.9
NARRABRI	**2016**	3.06	10.5	0.29	642	225	16	4.8
PAMPAS	**2021**	3.18^{B}	16.5	0.19	392	205	42	8.1
PAMPAS	**2015**	3.55	15.2	0.23	517	152	29	6.9

^{A} – Frost damage during early podding; ^{B} – Mouse damage removed 10-20% of pods.

Predicted yields and soil water

As shown in Table 1, seasonal variability and the availability of soil water at sowing are key drivers of yield expectations for canola in the northern region. In particular, soil water at sowing is far more important than in southern environments which receive more reliable winter rainfall. Figure 2 (below) highlights the extent to which different starting water conditions impact yield potential for canola in some example northern locations. This shows that the median yield increases by about 0.5 t/ha for every 50mm of extra PAW in the soil profile at sowing. To achieve a canola grain yield potential of >1. 5t/ha (a benchmark break-even yield under typical price-input scenarios) in >60% of years, soil water at sowing would need to exceed 150mm at Mungindi or Goondiwindi and exceed about 100mm at Narrabri. When PAW at sowing is <100mm, the likelihood of achieving grain yields >2.0 t/ha is low (i.e., less than 1 in 5 years at most locations).

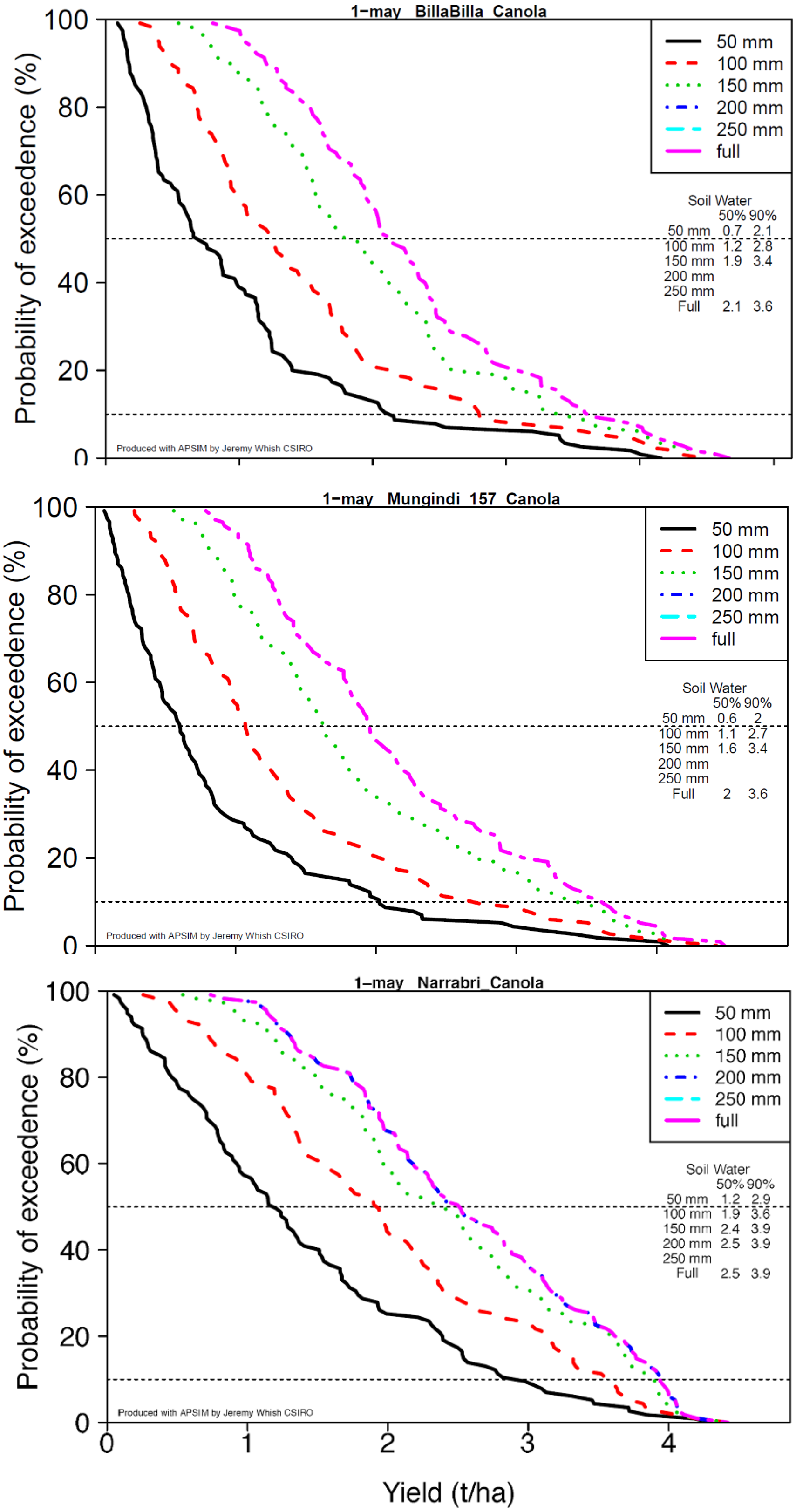

Figure 2. Simulated water-limited yield potential for canola across environments in northern NSW & southern Qld with different plant-available soil water conditions at sowing (indicated by different colours) (Top = Billa Billa, middle = Mungindi, bottom = Narrabri).

Mitigating risk of heat/frost stress

Mitigating the risks of frost and heat stress at flowering is critical for maximising canola yield. In particular, the period 200–400-degree days after flowering (i.e., at peak flowering) is a key stress point when the crop is particularly susceptible to temperature or water stress (Kirkegaard – GRDC update paper Wagga etc). Table 2 (below) shows the predicted optimal flowering windows for canola across various locations in southern Qld and northern NSW compared to a 'typical' canola growing region in southern NSW (Young – shown in bold). Firstly, the optimal window is typically shorter in our northern environments due to a shorter period when frost and heat stresses are minimised. This results in narrow sowing windows for canola to hit the narrow optimum flowering window. Secondly, the optimal flowering window varies significantly across environments – from the earliest situations at Mungindi in the west, to later at Warwick in the east. This means it's particularly important to look at this for your environment and select canola varieties with the appropriate phenology to hit this optimal flowering window for a particular sowing date. These issues can be explored for your location and specific situation using the Canola Flowering Calculator at: https://www.canolaflowering.com.au/

Table 2. Predicted optimal window to start flowering and sowing date for an example variety with early/fast phenology across various environments spanning the northern grains region compared to a traditional canola region at Young, NSW.

Location	Optimal window to start flowering	# Days in window	Optimal sow date for an early cultivar (e.g., Stingray)
Young	**13 Aug – 15 Sept**	**33**	**1 May – 17 May**
Narrabri	18 July – 15 Aug	28	1 May – 15 May
Moree	10 July – 8 Aug	29	26 Apr – 10 May
Goondiwindi	6 July – 2 Aug	27	20 Apr – 3 May
Walgett	12 July-6 Aug	25	26 Apr – 8 May
Mungindi	26 Jun- 23 July	27	19-26 April
Warwick	2 Aug -25 Aug	23	12 May – 20 May
Condamine	17 July – 12 Aug	26	3 May-15 May

Nitrogen management

Canola has a high nitrogen demand compared to other crops. Hence, understanding the nutrient status of paddocks planned for canola production is likely to be of particular importance to maximise yield potential. Current recommendations are to budget 70-80kg of N per tonne of target grain yield. So, for a 2.5 t/ha grain yield, a canola crop needs to have access to at least 175kg of N/ha. Relying on application of fertilisers at sowing to meet this large demand can be problematic, particularly in the northern region where in-crop rainfall required to move this fertiliser N into the soil profile is less reliable. There is also a high risk of seedling damage from high application rates of N fertilisers at sowing. Therefore, canola is likely to fit best when sown in situations where there's likely to be significant residual N through the soil profile at sowing. Applying 30-40% of budgeted N as a top-up around stem elongation is recommended to spread the N application out and enable N inputs to be adjusted to seasonal conditions.

Performance and legacy of canola compared to other crops

At various farming system sites, canola has been grown under comparable conditions to other winter crops, providing insights into its relative performance in terms of grain yield and legacies such as extraction and replenishment of soil water and N availability in subsequent crops.

Firstly, despite the variability in canola productivity shown above, canola has produced grain yields between 34 and 70% (average of 55%) of those achieved in wheat under the same seasonal conditions. Canola yields have typically equalled those achieved in chickpeas under comparable seasons. Of course, the relative prices and input costs required between these crops will influence a direct comparison of profitability.

Canola left similar amounts of soil water at harvest compared to winter growing cereal crops or grain legumes in the same season. Some small differences (<20 mm) occurred in some seasons where canola left 15-30mm more water than the winter cereals; often due to earlier termination of canola while the cereal was still finishing. Despite there often being a slightly lower fallow efficiency achieved after canola than following a winter cereal, in the seasons with comparisons of PAW at the end of the subsequent fallow, there was little if any significant difference compared to either the cereals or legumes.

One clear and consistent observation was that the nitrogen that accumulated during the subsequent fallow after canola was often 20-35kg N/ha higher than following a cereal. Similar results have been consistently reported in southern regions. This occurs because canola leaf residue has a lower C:N ratio, and hence breaks down more quickly and releases more N than from cereal residues.

Table 3. Differences between canola relative to a winter cereal (wheat, barley) or a winter legume (chickpea, fababean) grown in the same season in terms of grain yield, residual soil water (SW) at harvest, soil water and N mineralised over the following fallow.

Site-Year comparison	**Canola yield (%) relative to:**		**Canola harvest SW (mm) relative to:**		**Canola SW at sow next crop (mm) relative to:**		**Canola fallow N mineralisation (kg/ha) relative to:**	
	Wheat	Chickpea	Cereal	Legume	Cereal	Legume	Cereal	Legume
Trangie-Red 2019	34		+20		+17		+18	
Trangie-Red 2020	42		-8		-4		+30	
Narrabri 2017^A	0		+20		+17		+35	
Pampas 2015	68	95	-4	-9	+4	+2	+28	-10
Billa Billa 2018	60	108	+14	+3				
Trangie Gray ‘20	57	300	+28	-20				
Pampas 2021	70	123						
Narrabri 2016	-	108	-	0	-	-18	-	-10
Spring Ridge 2019	-	-		0		-14		+34

^{A} – Frost damage during early podding

Crop rotational implications

Weed and pathogen management

Clearly an important rationale for using canola in a crop sequence is to achieve some rotational benefits such as reducing populations of cereal or legume pathogens (e.g., root lesion nematodes, Fusarium crown rot), providing an alternative weed control option, and/or opportunities for using (or coping with) alternative herbicide chemistry.

Consistent with previous understanding, our farming system data has shown that canola does not host the root lesion nematode, *Pratylenchus thornei* (*Pt*), the main problem species in the northern region. Hence, the population of this pathogen continues to slowly reduce under a canola crop whilst it will increase significantly under host crops like wheat or chickpea. The benefit for supressing *Pt* populations is further enhanced if the period of growing non-host crops can be extended for >24 months (Figure 3). Hence, growing canola in combination with non-host crops like durum wheat, cotton, or sorghum provides an effective mechanism for reducing the population of *Pt* to low levels in problem fields. However, it should be noted that canola is a host of a different root lesion nematode species *Pratylenchus neglectus* (*Pn*) which is more dominant on lower clay content soils in central and southern NSW. Hence, canola is not a good option for lowering *Pn* populations in these regions. Canola has also been shown to be a valuable alternative crop in northern cropping systems to reduce levels of Fusarium crown rot following winter cereal crops (Kirkegaard et al. 2004).

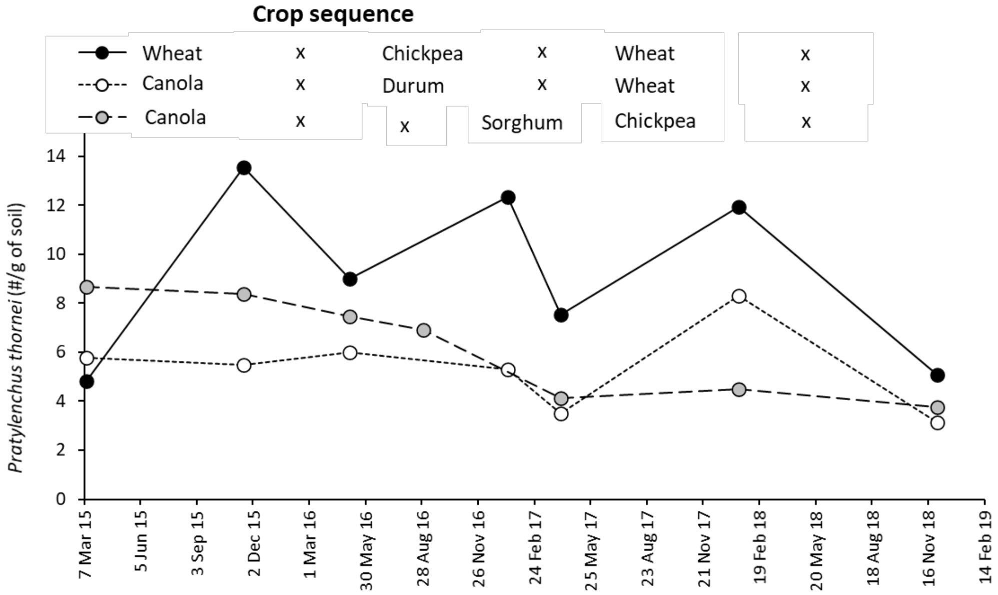

Figure 3. Root lesion nematode (*P. thornei*) populations in the soil over different crop sequences – shows the slow decline in numbers during non-host crops like canola coupled with durum or sorghum to provide a double break, compared to a rotation of host crops like wheat and chickpea.

Other crop rotational impacts/considerations

While canola can offer several positive legacy benefits in a farming system, there are some potential risks to consider in subsequent crop management and selection. Firstly, canola doesn't host beneficial arbuscular mycorrhizal fungi (AMF), so there's a risk that these populations will be reduced during a phase of canola, especially if it is preceded or followed by a long fallow, creating a long period without a host plant. Hence, on sites with low or marginal soil P, it is probably best to avoid following canola with a more AMF dependent summer (cotton, sunflower, mungbean and maize) or winter crop (linseed, chickpea and fababean). Secondly, several herbicides used in canola can have significant plant-back restrictions for some crop choices. This is important to consider in situations with double-crop opportunities into summer crops (e.g., mungbeans, sorghum). Finally, volunteer canola plants, particularly when growing herbicide tolerant canola varieties, can be difficult to control in some subsequent crops and fallows. This can sometimes require more expensive herbicides be used to clean up canola volunteer plants in fallows or control these in the following crop.

Conclusions

Canola offers many potential benefits of crop diversification in a farming system; widening sowing windows, disease and weed management. Both experimental data and modelling suggest there are opportunities to use canola in northern farming systems when we have the confluence of sufficient accumulated soil water and a sowing opportunity in the right window. Whilst these conditions are unlikely to occur every year, they are not infrequent across many environments in the northern grain region.

While considering many of the agronomic considerations outlined above, it is important to also consider the sowing and harvesting equipment available to you. Accurate seed depth control will achieve better and more consistent establishment in canola, and hence sowing machinery that provides this is advantageous. Similarly, accessing a windrower for canola is often challenging and whilst direct heading is possible, it does impose greater risk of harvest losses and requires more attention to timing of harvest to mitigate risk.

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Optimising sorghum agronomy in northern NSW and southern Queensland

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Key words

early sorghum, yield, quality, water use

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Take home messages

- Planting once soil temperatures are at 12 ℃ and rising provides an opportunity for early sowing and establishment of grain sorghum in late winter, with a very low risk of frost damage after 7 leaves or floral initiation
- Early (winter) sown sorghum has an extended period of vegetative growth meaning the crop takes more days to reach flowering, but the flowering window is still 2-3 weeks earlier than a normal spring planting time
- Sowing early reduced the likelihood of heat stress around flowering at most sites. Early sown sorghum also has a lower risk of a dry finish (terminal water stress), which reduces the potential for screenings and minimises or eliminates the risk of lodging
- The yield of early sown sorghum was similar or higher than sowing in spring and summer across all sites from the Liverpool Plains in NSW up to Emerald in Central Queensland
- Water use efficiency (kg/mm) has tended to be higher with early sown sorghum. This is largely explained by the crop growing during a cooler time of the year
- Early sown sorghum used more water than a summer sown sorghum crop. Most of this additional water was used in the flowering to maturity stage to complete grain fill and support realisation of a larger yield potential
- At the cropping system level there is an increased likelihood of double cropping after early sown sorghum, as the resulting earlier harvest increases the opportunity for fallow recharge facilitating short fallowing back into a winter crop
- Analysis of the first two seasons of trials (2018-2020) across 15 sites from the Liverpool Plains in NSW to Emerald in Qld, showed that at each site the combination of hybrid, sowing time and plant population created up to a 66% difference in grain yield.

Background

Australia's climate has warmed by about 1.4 °C since 1910, and an increase in the frequency and intensity of extreme heat and water stress can be expected. The main challenge of growing a profitable sorghum crop in the Northern Grains Region is the need to avoid periods of extreme heat around flowering and reduce the likelihood of water stress between flowering and grain fill. Extreme heat at flowering causes pollen sterility that reduces grain number, the main determinant of final yield. In addition, water stress during grain filling will increase screenings affecting sorghum grain quality and may also induce lodging.

One adaptation tool to reduce risk in sorghum involves moving the planting window earlier into late winter. The main aim being to avoid the overlap of crop sensitive growth stages with the hottest and driest times of the year.

An earlier planting window also has other benefits, including an increased number of sowing opportunities, higher and more stable grain yields in some sites and seasons, and improved grain quality. Farming system benefits of earlier planting include higher cropping intensity through increasing the opportunity for double cropping after early (winter) sown sorghum.

This paper is a summary of current results from the Optimising Sorghum Agronomy program funded by a collaboration between GRDC, UQ-QAAFI, NSW DPI and QDAF from 2018-2022. The program conducts replicated field experiments in collaboration with farmers from the Liverpool Plains in NSW up to Emerald in Central Queensland.

Establishing a uniform crop

Soil temperature

Soil temperatures of 16-18 ℃ have historically marked the start of the sorghum planting window. Results from this project have supported the idea of moving the planting window earlier into late winter (from mid-August) in Southern Qld and Northern NSW if soil temperatures have reached 12 ℃ and are predicted to continue rising for at least 7 days following planting.

Planting into these cooler soil temperatures does mean that the time from planting to emergence is extended, as seedling development occurs at a slower rate. As such, emergence is anticipated to occur in 7-14 days rather than the 3-7 days experienced under warmer soil temperatures (>18 ℃).

Slow emergence creates an opportunity for increased damage by soil dwelling insects, competition from late emerging winter weeds, and the potential for reduced plant establishment. Selecting suitable paddocks with low weed burdens and treating seeds with insecticide are important tools to reduce the risk of weed competition and insect damage.

Establishment will also be optimised when adequate seed bed moisture is available for 2 weeks post planting, using quality seed and focusing on planting depth (not too shallow or deep).

When soil temperatures of 12 °C, good seedbed moisture and reasonable seed quality are combined, it is possible to achieve plant establishments of commercially acceptable levels, ~ 80% such as at the Mungindi site in 2021/22 (Figure 1).

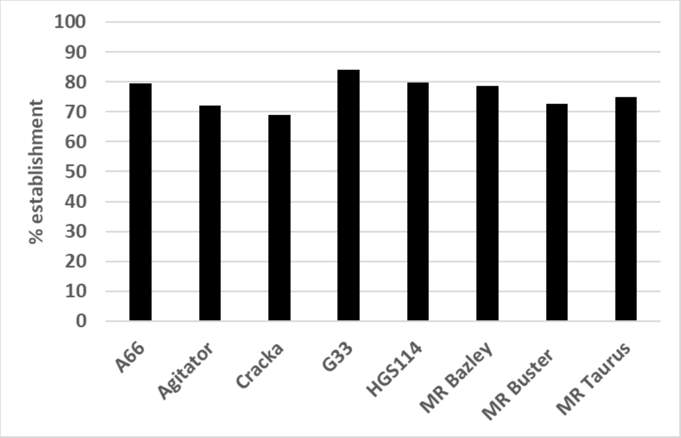

Figure 1. Sorghum plant establishment at Mungindi in 2021/22

Seed quality

Seed quality varies between hybrids, seasons, and seed batches with all crops. Information on the germination and vigour of sorghum seed to be used for sowing can be useful to ensure establishment is optimised in each planting situation.

The largest factor affecting plant establishment in our trials has been inherent seed quality, i.e., germination and vigour. For example, results of seed quality testing of the trial seed to date have shown high variability in seed lot germination percentages (Figure 2) between hybrids, seed lots and across temperatures. Larger differences in germination appeared between hybrids as the temperature was increased from 15 to 35 °C, with germination reducing at the higher temperature (Figure 2).

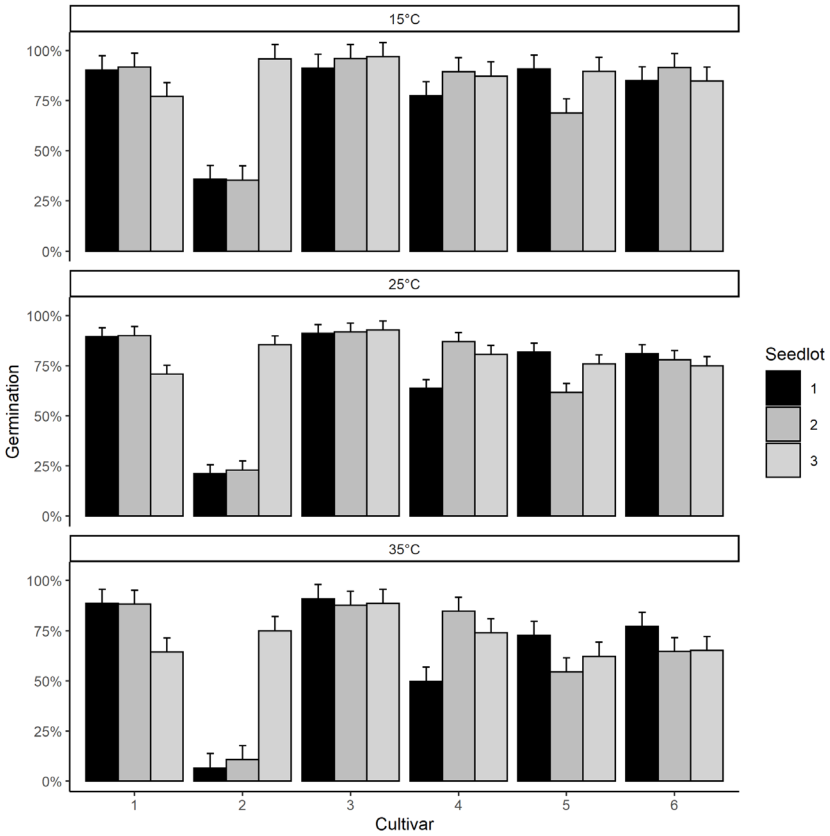

Figure 2. Germination percentage for each genotype and seedlot used in trials between 2018 and 2021 at 3 temperatures. Seedlot 1 was sourced in 2018-19, seedlot 2 was sourced in 2019-20 and seedlot 3 was sourced in 2020-21. Seed was kept in cool storage until evaluation in 2020. Error bars show pooled standard error (n=4).

What about the risk of frost damage?

Early (winter) sown sorghum trials have not been significantly damaged by frosts in northern NSW and southern Queensland when planted from early-mid August onwards. Sowing early reduces the likelihood of heat stresses around flowering across most sites, with a very low historical risk of frost damage i.e., frosts after 7 leaves or floral initiation (Figure 3). That is not to say that frost damage will never occur, but the risk is low.

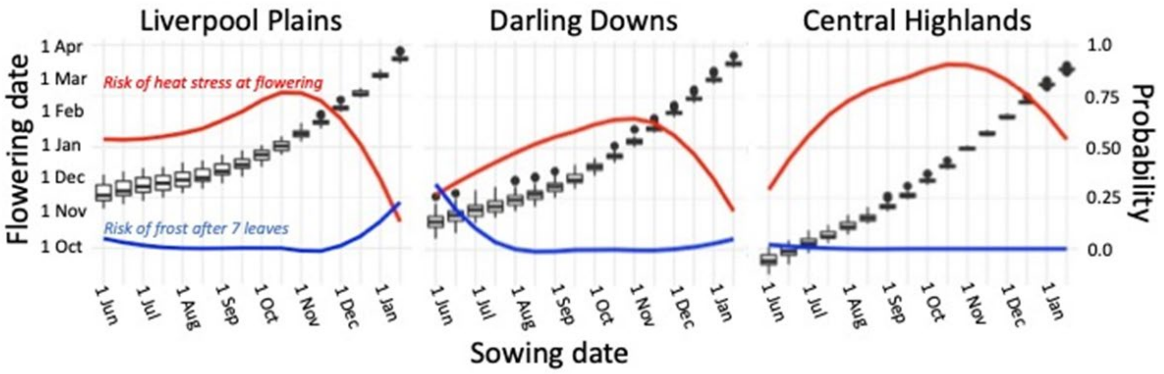

Figure 3. Sorghum flowering date for a range of sowing dates (black boxplots) at Breeza, Liverpool Plains NSW (a); Dalby, Darling Downs Qld (b); and Emerald, Central Queensland (c). The red lines show the probability of a heat stress event at flowering, defined as a maximum temperature higher than 36° C around a 7-day window centred at flowering. The blue line shows the probability of a damaging frost, defined as air temperature lower than 0° C after the sorghum crop has 7 leaves (floral initiation) and becomes sensitive to frosts. Climate records are from 1980-2021.

Crop development

Early sown crops grow under cooler temperatures and a lower photothermal quotient. This results in more tillers and longer vegetative and panicle growth stages. As a result, it takes more days to reach 50% flowering when compared to a more typical (later) spring sowing date (Table 1).

Table 1. Days to 50% flowering for eight hybrids planted 11th Sept, 8th Oct and 28th Oct, 2019 at Breeza

Hybrid/ Sowing date	11th Sept	8th Oct	29th Oct
A66	90	81	70
Agitator	89	78	70
Cracka	107	90	82
HGS114	91	85	73
MR Bazley	92	83	73
MR Buster	96	86	76
MR Taurus	95	85	74
Sentinel IG	103	88	77

Even with a longer period to reach flowering, early sowing still moves the flowering window forward. This was demonstrated at “Bogamildi” Moree, when comparing three sowing times (Figure 4).

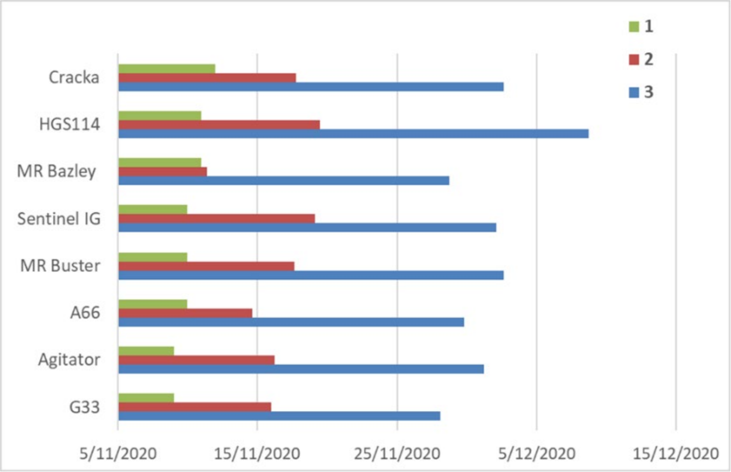

Figure 4. Flowering dates at "Bogamildi" Moree in 2020-21. Sowing dates were (1) 5th Aug, (2) 2nd Sept and (3) 28th Sept.

Water Use Efficiency (WUE)

Sorghum is primarily grown in dryland systems, so water use and water use efficiency (WUE) are important measures of crop productivity. Changes in agronomic management, such as shifting the planting window which affect plant development should be expected to have an impact on crop water use.

APSIM was used to simulate the WUE using data from the crop biomass and yield measurements collected from each trial. At both the Breeza and Moree sites (Figure 5), WUE is predicted to be higher from the earlier sowing times. The higher WUE of the early (winter) sown sorghum crop was explained by the crop growing during a cooler time of the year (i.e., lower atmospheric demand), and a relatively smaller canopy size at flowering.

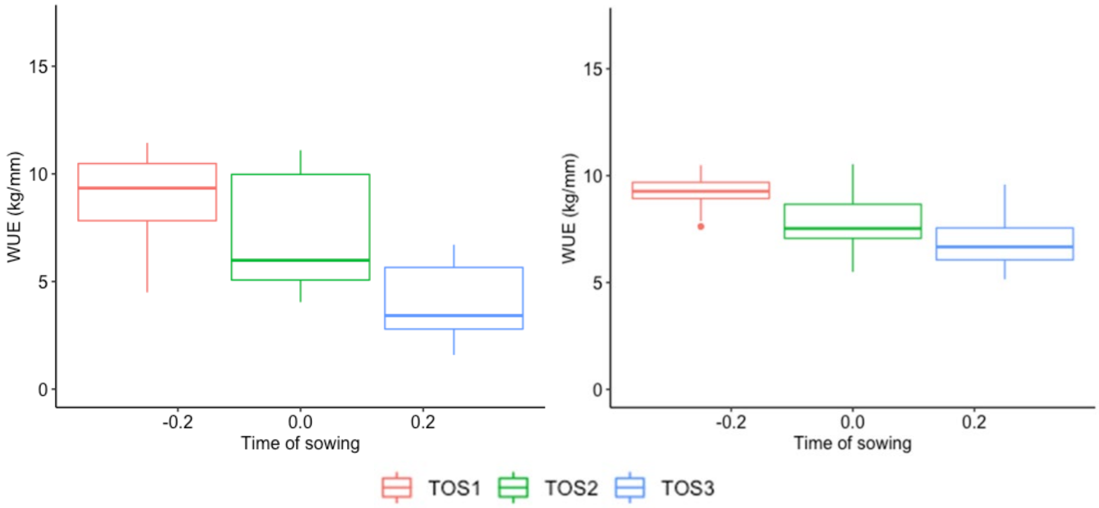

Figure 5. Simulated water use efficiency (WUE) from APSIM using biomass and yield from Breeza (LH) and Moree (RH) trials in 2018-20.

APSIM simulations were also used to compare total water usage. Total water use varied with the planting time and the crop development stage (Figure 6). When collated to produce a total seasonal water use, the two earliest sowings (winter and spring) used more water than the summer sown sorghum.

Once this water use was partitioned into the key development stages; emergence to 7 leaves (floral initiation), 7 leaves to flowering, and flowering to maturity, the response varied. In the emergence to 7 leaf stage, more water was used from a summer planting which correlates with higher temperatures and more rapid plant growth rates. In contrast from flowering to maturity, more water is used by the early (winter) sown treatment. Compared to the spring sown crop, the winter sown crop had an additional 30 mm of water available in the soil profile which was used between flowering and maturity (Figure 7).

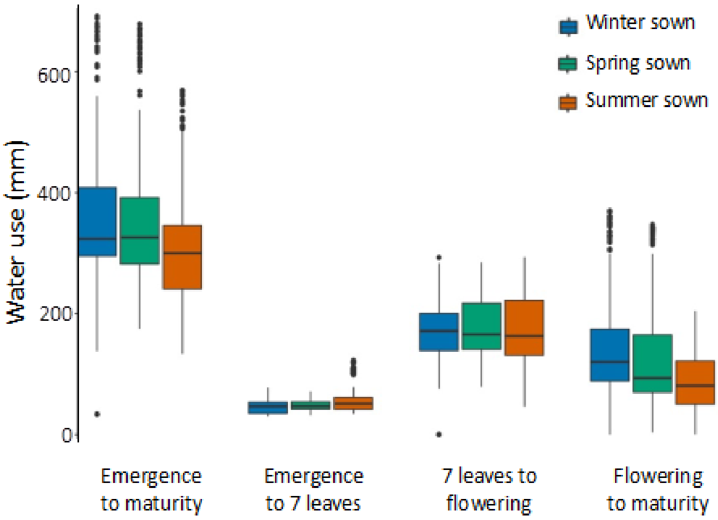

Figure 6. Modelled crop water use (mm) for three times of sowing (winter, spring, and summer) from crop emergence to maturity, emergence to 7 leaves (or floral initiation), 7 leaves to flowering, and flowering to maturity. Results are APSIM simulations for the 15 sites and combined three times of sowing, six commercial hybrids and four plant populations, sown across the Liverpool Plains, Northern NSW, Darling Downs, Western Downs and Central Queensland for the 2018/19 and 2019/20 seasons.

Actual water use was measured in selected treatments at the Breeza and Mungindi sites using a neutron moisture meter. Total water use efficiency was measured at the Breeza (Figure 7) and Mungindi (Figure 8) sites in the 2021/22 season. The overall water use efficiency was slightly higher from the summer planting time at Breeza in this season, which had the benefit of one small flood in early December and in-crop irrigation in mid-January (Figure 7).

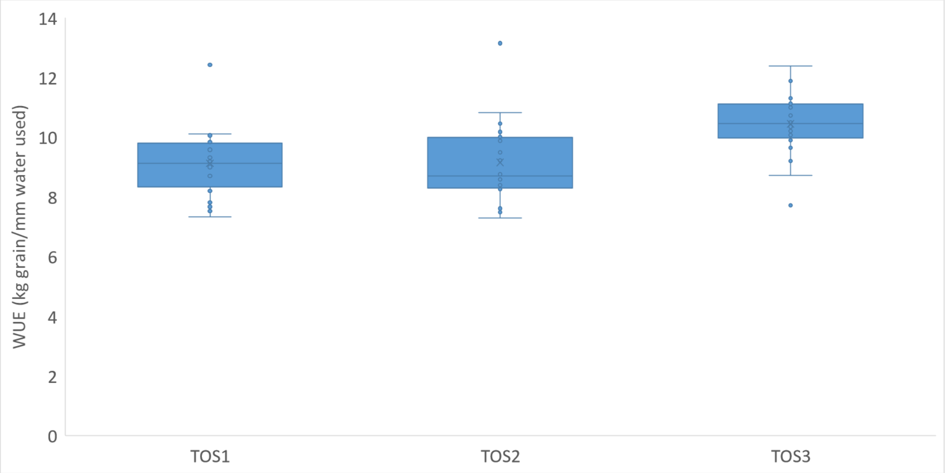

Figure 7. Measured water use efficiency at Breeza 2021/22 using neutron moisture meter for TOS 1 (16th Sept), TOS 2 (7th Oct) and TOS 3 (3rd Nov).

In contrast, water use efficiency was higher from the early planting at Mungindi which also received a significant flood for 3 weeks over the grain fill period. The overall water use efficiency was very high for both times of sowing (Figure 8).

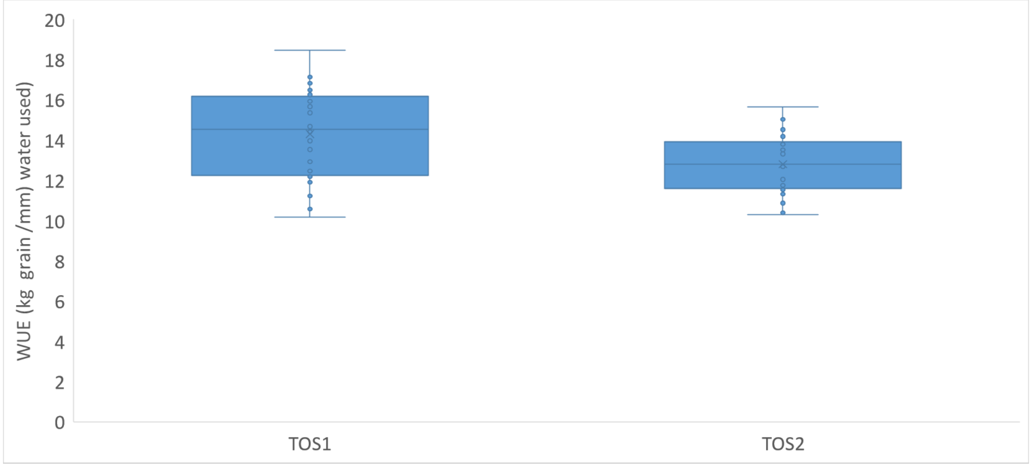

Figure 8. Measured water use efficiency at Mungindi 2021/22 from TOS 1 (18th Aug) and TOS 2 (6th Sept).

Grain yield and quality

The impact of varying sowing time on grain yield was measured at each of the trial sites from 2018-2020. The range in grain yields from the trial sites was from < 1 t/ha up to 12 t/ha under both dryland and irrigated conditions.

Across all these environments and seasons, the yield of early (winter) sown sorghum was similar or higher than that of later sowing dates (Figure 9a). This was associated with higher seed set (Figure 10b) due to a reduced incidence of heat stress around flowering. As grain number is the largest determinant of yield, any strategies which improve seed set are critical to the final crop success.

Grain quality was also improved with early sowing resulting in improved grain size (reduced screenings). This was due to increased availability of soil water later in the season (Figure 9c).

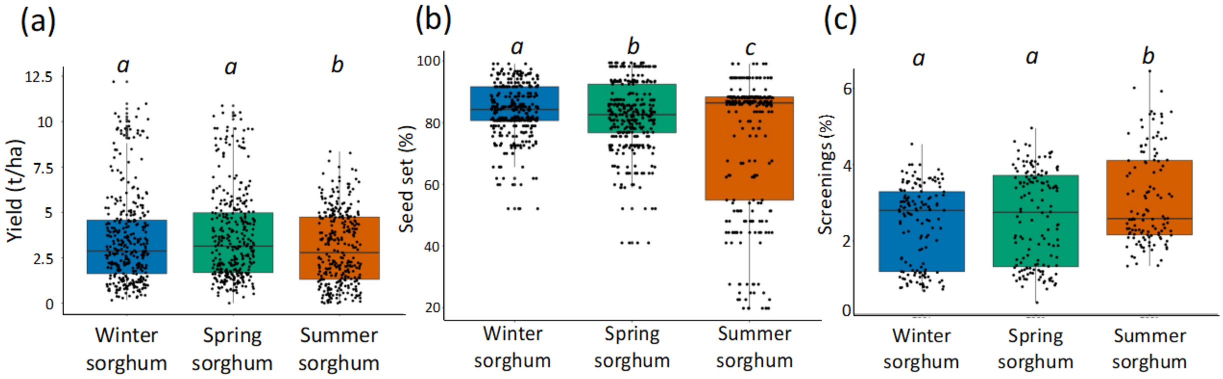

Figure 9. Outcomes from 15 trials sown across the Liverpool Plains, Northern NSW, Darling Downs, Western Downs, and Central Queensland for the 2018/19 and 2019/20 seasons. (a) Mean yields for the three tested times of sowing (winter, spring, and summer); (b) the estimated seed set from the incidence of extreme air temperature events around flowering; and (c) percent screenings. Different italic letters on top of the boxplots indicate statistically significant differences (p<0.05).

Where to next?

As we gain confidence in the practice of early (winter) sowing in sorghum, we need to consider what are the next possible step changes we can adopt which could further improve sorghum productivity and reliability. While most of the focus to date has been on shifting the planting window, there have also been large yield gains demonstrated in this project, achieved through pairing the optimised planting time with a preferred hybrid and plant density.

The 2018-2020 trial set highlights the large variation in yield measured (~66%) across all treatment combinations; hybrids (G), planting times and plant populations (M) (n=3,072), indicating that informing optimum Genetics x Management for each system is critical to maximising crop performance (Figure 10).

The development of regional agronomic packages which identify these combinations will provide valuable information for decision makers. Our ability as an industry to implement these packages to reap the resulting yield and profitability benefits, will be core to ensuring sorghum becomes a viable crop option in marginal areas and its potential is exploited within northern cropping systems.

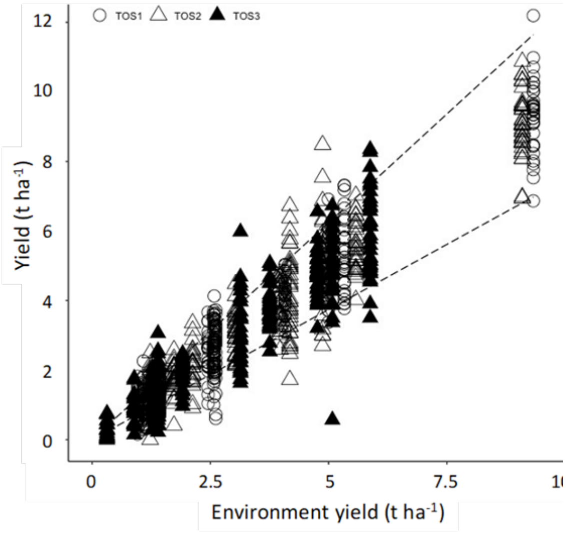

Figure 10. Grain yield as a function of the environment yield (average treatment yields for each site x season x time of sowing) for 2018-2020 with different time of sowing. Open circles indicate very early (TOS 1), open triangles early (TOS2) and closed triangle normal (TOS3).

Conclusions

There are significant opportunities available to optimise sorghum production in Northern NSW and Southern Queensland. The first of these options is to move the sowing window forward as a tool to reduce the risk of heat and moisture stress at anthesis and grain fill.

To date, early sown (winter) sorghum has provided benefits which have far outweighed the risks. The integration of additional tools to help growers develop knowledge on seed quality impacts (germination and vigour), methods to improve plant establishment, prediction of hybrid flowering time and overall crop water use, will improve our confidence in sorghum production.

The optimum management package will suggest avoidance of the peak heat and moisture stress periods in the northern grains region and generate a profitable sorghum grain yield with optimised water use efficiency, whilst still maintaining system benefits such as stubble cover from a cereal crop. This is a significant challenge for the future of our industry, but also a massive opportunity for sorghum production which is waiting to be exploited.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the financing of the GRDC. The authors would like to thank them for their continued support. The authors also acknowledge the collaboration between QDAF, NSW DPI and UQ-QAAFI, and participating technical staff. Thanks also to the participating seed companies for their continued support.

The support of Andrew Earle “Bullawarrie” Mungindi, Tom & Melissa Greentree “Quissisana” Mungindi, Geoff Manchee & JR McDonald “Bogamildi” Moree, Michael Brosnan, B&W Rural Mungindi and the Mungindi Cropping Group and is also gratefully acknowledged.

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Managing problem summer grass weeds with pre-emergents

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and Richard Daniel[1]

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Key words

feathertop Rhodes grass, *Chloris virgata*, residual, management

GRDC codes

NGA00003, NGA00004 and NGA2009-001RTX

Take home messages

- Feathertop Rhodes grass (FTR) poses a major challenge due to the lack of low cost, effective knockdown herbicide options
- Effective pre-emergent chemistry options are available from a range of mode of action groups
- Winter/spring residual application prior to sorghum appears promising to improve FTR control
- At-planting residual options in wheat are unlikely to assist due to the length of residual control required, crop safety constraints and high cost for an 'insurance' type treatment.

Background

Management of summer grass weeds has become a significant economic cost and major agronomic challenge in many areas of the northern grain's region. This can be as a result of: selection of resistant/ tolerant grass populations from prolonged use of glyphosate, reduction in grass weed efficacy when broadleaf herbicides are tank mixed with glyphosate, reduced efficacy due to temperature/heat stress at application or delays in application timing.

Regardless of the reason, growers need a range of alternative management approaches to assist with key problem grass weeds. This paper will focus on the potential and fit of residual herbicides for the management of feathertop Rhodes grass (FTR), which has in recent years become the major problem summer grass across the region. Some of the strategies discussed are also applicable to problem weeds such as awnless barnyard grass, however differences in the ecology of FTR allow consideration of alternative management strategies.

1. Summer fallow management with residuals

The most successful strategies employed by growers for managing FTR have included the use of residual herbicides. Either directly targeted at known FTR problem paddocks, or more broadly, by keeping FTR at bay when targeting other grass weed problems on the farm. The viability of most other grass weed seeds in the soil is longer than for FTR, so when growers are incorporating residual herbicides into their program to manage grass weeds such as awnless barnyard grass, FTR is often also controlled or suppressed.

Balance® can be a particularly effective option for fallow management. In addition to residual control of FTR, it will also control flaxleaf fleabane and common sowthistle with suppression of awnless barnyard grass, however significant plantback periods apply for many summer crop options.

Dual Gold® is registered for residual control of FTR prior to planting a wide range of summer crops and also in fallow situations, with minimal plantback constraints. A new use pattern also allows for a top-up application in sorghum after crop emergence.

Valor®, applied at rates for residual control, is registered in summer fallow but is also an option prior to planting selected summer crops. Plantback periods apply for some summer crops when using Valor, so always check the label. In addition to control of FTR, Valor can also provide residual control of a range of difficult to control broadleaf weeds such as flaxleaf fleabane, common sowthistle, red pigweed, caltrop, bladder ketmia and *Ipomea* species such as bell vine and morning glory.

Figure 1 shows a snapshot of efficacy results from registered fallow options at varying periods after application. The blue columns show residual control when assessed in the first 48 days after application, orange columns show levels of control when assessed 58-77 days after application and the grey columns show levels of control 81-147 days after application.

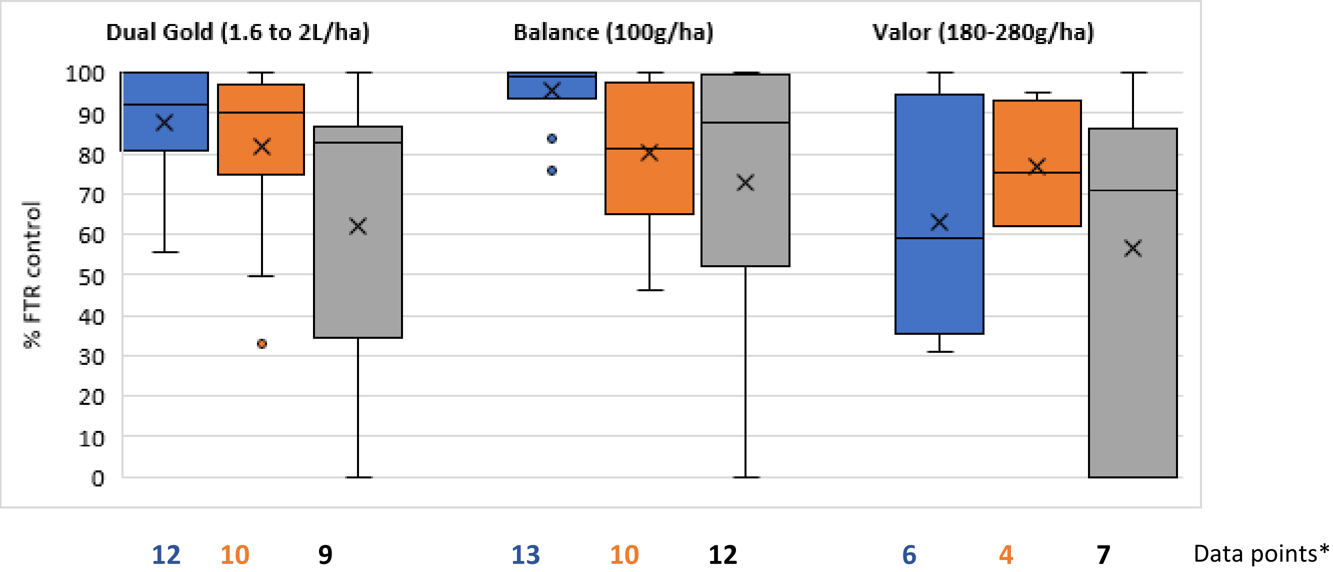

Figure 1. Summary of 22 residual herbicide trials (2007-2016) (NGA, QDAF, GOA, NSW DPI)
Blue 14-48 DAA Orange 58-77 DAA Grey 81-147 DAA

**Not all treatments were included in all trials. Some trials had more than one rate of herbicide included. Some trials had two ratings within the same time grouping.*

2. Winter/spring fallow management with residuals

Although FTR is generally considered a summer grass weed, emergences can be seen in winter. Field experience suggest that periods of soil wetness are more important than temperature for FTR germination and emergence.

Glasshouse studies by Queensland Department of Agriculture and Fisheries (Werth 2017) showed that FTR will emerge following as little as a 10mm simulated rainfall event however larger rainfall events resulted in increased emergence.

Awnless barnyard grass, common sowthistle and flaxleaf fleabane were also included in the same study. The rainfall requirement for emergence of FTR was less than for awnless barnyard grass, especially at cooler temperatures (15/20^{0}C compared to 20/30^{0}C), while rainfall >20mm was required to provide significant emergence of common sowthistle and flaxleaf fleabane. The ability of

FTR to establish on lower rainfall highlights one of the reasons that FTR is often the first weed to establish following spring rainfall.

Both the field and glasshouse experience indicate FTR emergence, particularly during July to September is likely to be a more frequent and bigger management risk than for awnless barnyard grass.

The management risk for FTR in the winter/spring fallow prior to sorghum planting is further increased due to the lack of effective, low cost, non-residual knockdown options. This is particularly of concern when FTR emerges in a window from ~4-6 weeks prior to sorghum planting up until planting.

Dual Gold and Valor both have fallow registrations and plantback profiles to enable use in a winter/spring fallow situation, particularly prior to sorghum.

Data from a trial at Nandi in 2021 (~18 km SW of Dalby) highlights the benefit of residual management for FTR. This was one of a series of four trials conducted in 2021.

Case study - Nandi trial near Dalby in 2021

Rainfall

August and September were both dry with total rainfall of <10 mm in each month. Two rain events occurred in October prior to planting; 17 mm over 2 days (~2 weeks pre-planting) and 32 mm over 3 days (3-5 days pre-planting).

Residual treatments

Dual Gold at 1 L/ha or Valor 210 g/ha were applied at the end of July and end of August as single applications to compare with the same timings ‘topped up’ with Dual Gold 1 L/ha at planting. Rainfall of <2 mm was received in the week following both the July and August applications. All treatments were compared to Dual Gold applied at planting.

Figure 2 shows the counts of FTR shortly after planting and highlights the residual control achieved from either Dual Gold or Valor applied at the end of July or August. A commercial knockdown of glyphosate was applied at planting and the trial area also received an additional glyphosate application following the emergence count in Figure 2.

Figure 3 shows the counts of FTR ~ 2 weeks later. It highlights that:

- Applications of Dual Gold at planting reduced FTR counts from ~ 100/m^2 (where no residual was applied) to ~30-50/m^2
- In contrast where either Dual Gold 1 L or Valor 210g were applied alone in July or August, FTR counts were ~1-10/m^2
- When the July or August applications were ‘topped up’ with Dual Gold 1L at planting, FTR counts were ~1-2/m^2

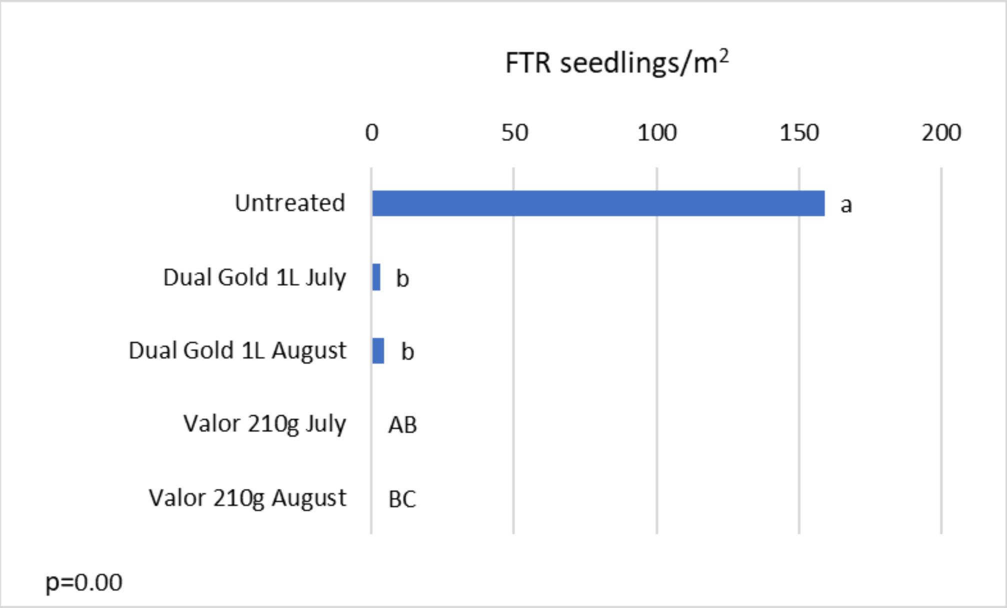

Figure 2. Feathertop Rhodes grass counts at 21/10/2021, 4 days after planting

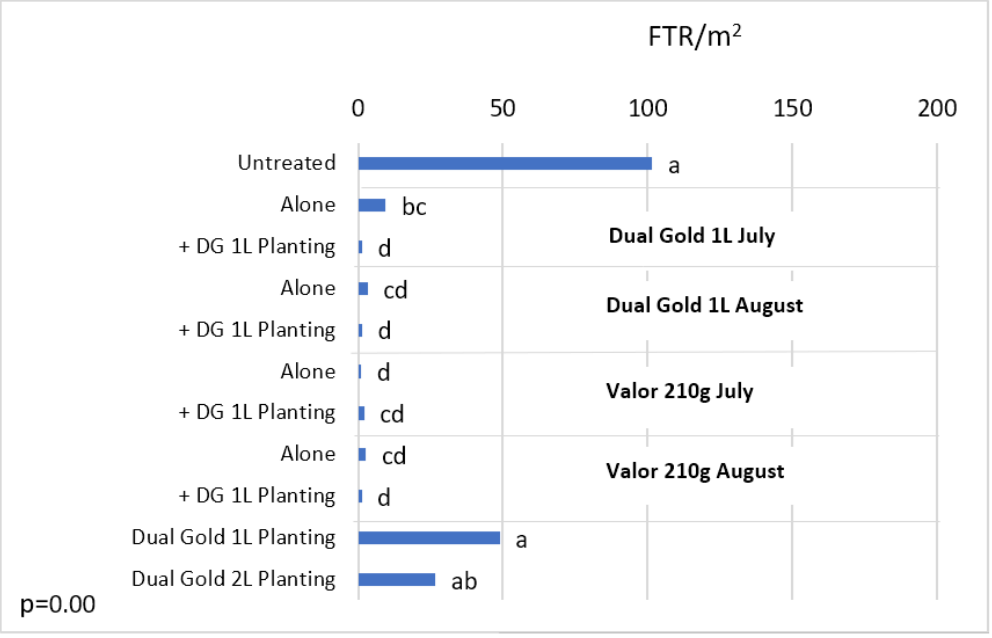

Figure 3. Feathertop Rhodes grass counts at 5/11/2021, assessed 19 days after planting following July or August applications of either Dual Gold or Valor +/- 1L Dual Gold at planting

NB + DG 1L Planting is a 'top up' of Dual Gold 1L at planting following the initial herbicide treatment in July or August

Similar results to those shown occurred at a second site, but with untreated FTR densities of only 1-2/m^2. Only trace levels of FTR (<0.2/m^2) emerged at the other two sites despite a history of FTR issues.

Trial activity is continuing in 2022, with the additional aim of quantifying the impact of incorporating rains on Dual Gold activity under winter conditions.

Similar trials have been conducted with awnless barnyard grass as the primary target. In trials to date, barnyard grass emergence has only occurred post planting with no clear benefit (or disadvantage) from the split application treatments compared to application at planting only.

3. Management with residuals in wheat

FTR management issues are not only associated with summer crop or fallow situations. It is not unusual for FTR to emerge in winter cereal crops, particularly when crop emergence has been patchy or thin or where crop growth had been restricted due to late planting or adverse weather conditions.

Where winter cereals are planted into high risk FTR situations, the best management approach is to ensure the crop provides maximum crop competition. Key factors are: timeliness of sowing, seed quality, planting depth, uniformity of emergence, row spacing and crop density.

Residual herbicides that are applied at wheat planting and registered for other grass weeds have been evaluated for FTR management. Many of the herbicides used for annual ryegrass management also have useful levels of residual activity on FTR. However, there are a number of key challenges to this management approach:

- Despite many of these herbicides providing useful FTR control for periods up to 10-14 weeks, applications in May are likely to be failing when FTR is most likely to be emerging in late winter or spring in-crop
- A number of the annual ryegrass active herbicides have crop safety constraints which may offset any FTR benefit
- Most annual ryegrass active herbicides are high cost, making them poorly suited to an ‘insurance’ type use pattern.

There are currently no herbicides registered for the control of FTR in winter cereals and it is unlikely that any at-planting residual herbicides will proceed to FTR registration. An option that may provide future FTR management benefit is where residual grass active herbicides can be applied in-crop, much closer to when FTR emergence is likely to occur, however more research needs to be conducted before this is a possible option.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

Reference

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P dynamics in vertosols - factors influencing fertiliser P availability over time and the implications for rate, application method and residual value

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Key words

P sorption, PBI, P saturation indices, deep bands, P incorporation, residual value

GRDC codes

UQ00063, UQ00082, UOQ1905-009RTX, UQ00086

Take home messages

- Fertiliser P is an increasingly important contributor to profitable cropping and efficient use of available water and nitrogen
- The method of P application, soil characteristics and seasonal moisture availability will significantly impact the recovery of fertiliser P by plants. Starter P is important but only supplies a small proportion of the crop total P requirement in the year of application
- Dispersing or spreading P fertiliser through large soil volumes to increase root exposure to fertilised soil reduces the risk of P precipitation but enhances the risk of low crop recovery due to strong P sorption to soil surfaces. This risk is enhanced when soil P reserves are strongly depleted and occurs somewhat independent of PBI
- Conversely, applying P in concentrated bands limits the risks of irreversible P sorption but increases the chances of precipitating insoluble P minerals – particularly when fertiliser bands are acidic and/or co-application of other cations like K increases calcium availability in the soil solution
- Fertiliser strategies need to balance the competing risks and rewards from differing volumes of soil P enrichment, while ensuring adequate available P in both topsoils and immediate subsoil layers to meet water limited crop demands
- Closer spaced, less concentrated P bands applied more frequently hold the keys to more effective crop P use in these soils and will increase the return of P in crop residues to enhance the background P supply in topsoil layers.

Introduction

Many Australian Vertosols were originally characterised by moderate, and in some cases quite high, phosphorus (P) fertility. However, declining soil organic matter, net positive nutrient removal (including P) in grains and increasing stratification of P in shallow topsoil layers has led to increasingly widespread occurrences of P limitations to yield. An overly simplistic solution to this problem would be to simply increase the inputs of fertiliser P into the rainfed cropping systems to balance removal, or even to partly rebuild the soil P bank. However, as research has shown in recent years, this is not a simple task due to two main factors. Firstly, P is held very tightly to solid surfaces (clay minerals, organic matter) in these clay soils, with the resulting low concentrations of P in the soil solution. Because P is tightly held by clay minerals any fertiliser P, and P released from decomposing residues (stubbles), effectively remain in the shallow topsoil layers where they are placed. Secondly, our rainfed cropping systems rely heavily on subsoil moisture stored during fallows to support growth during periods (in some cases, whole growing seasons) when the P-enriched topsoil layers are dry. The impact of this periodic topsoil drying on the availability of P to crops, regardless of the amount of topsoil P applied, is illustrated in Figure 1 (reproduced from Raymond *et al*., 2021). While P stress is a dominant limit to growth in all seasonal conditions without applied P, we see alternating water and P stress occurring in treatments with a highly P-enriched topsoil, with P stress typically observed during drier periods as the topsoil moisture content drops.

These responses clearly illustrate the vulnerability of fertiliser P strategies that focus only on the topsoil layers, and hence the need to consider not only increased fertiliser P inputs but also how that P is placed in the soil profile to improve seasonal P availability.

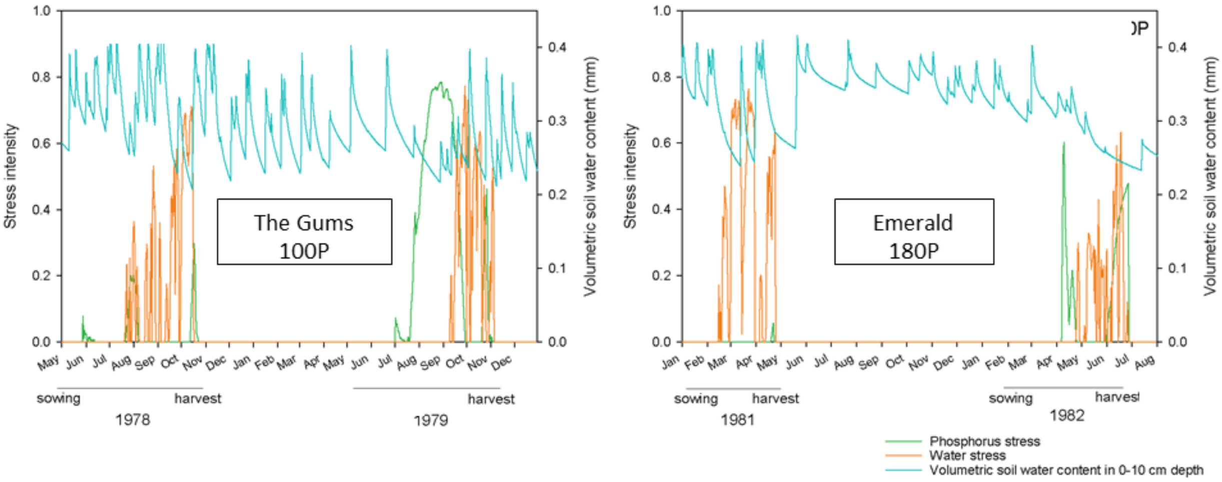

Figure 1. Simulated interactions between crop-water stress (orange solid line), P-stress (green solid line) and soil water content in the topsoil layer (10 cm, magenta line) in successive 'high yield' (initial) and 'low yield' (second) growing seasons, based on trials from The Gums and Emerald. Plots had 100 kg P ha^{-1} (100P) and 180 kg P ha^{-1} (180P) mixed into the top 10cm soil layer for The Gums and Emerald respectively. Simulations produced with APSIM and reported in Raymond et al. (2021).

Fertiliser strategies to address declining soil P fertility

Deep P banding:

The stratification of P reserves in topsoil and the vulnerability of crops to P deficiency in drier seasonal conditions, regardless of profile moisture availability, saw the development of the GRDC supported deep P program that was conducted across a wide range of field sites from 2013 to 2021. This focused on the placement of P deeper into the soil profile (typically 15-25cm) in concentrated bands was designed to improve plant access and uptake of P and preserve of topsoil structure and residue cover. While generally very successful and able to generate significant (Table 1) and profitable responses to applied P in most situations, responses did vary with seasonal conditions (yield potentials and access to topsoil layers) and were driven by relatively small increases in crop P uptake in many instances (e.g., typically only 2-4 kg P ha^{-1}: see Bell et al. 2022).

Table 1. Yields for the farmer reference treatment (Y_0) and the greatest deep P response (Y_{max}) for each site and season. Symbols (*) indicate yield increase was significant ($P<0.05$). *Cited from Bell et al. (2022)*

District	Crop 1#		Crop 2		Crop 3		Crop 4		Crop 5		Crop 6	
	Y_0	Y_{max}	Y_0	Y_{max}	Y_0	Y_{max}	Y_0	Y_{max}	Y_0	Y_{max}	Y_0	Y_{max}
Dysart	2.6	3.5*	2.7	3.5*	1.8	2.5*	0.4	1.4*	2.3	3.8*	1.2	3.6*
Clermont	1.6	2.7*	0.3	1.3*	1.5	1.5	-	-	-	-	-	-
Dululu	3.9	4.2	2.7	3.3*	0.7	0.9	0.4	1.3*	-	-	-	-

Crop sequences were – Sorghum-sorghum-sorghum-chickpeas-sorghum-chickpeas at Dysart; Sorghum-chickpeas-sorghum at Clermont; and Wheat-chickpea-mungbean-chickpea at Dululu.

Despite these strong yield responses, the yield response to increasing rates of deep banded P was often linear, suggesting that deep banding was often not able to completely overcome P limitations to grain yield. The reasons for this are still under investigation but are thought to be due to the limited volume of soil P enrichment (Figure 2a), the intense competition between roots that proliferate around these spaced P bands (Figure 2b - van der Bom *et al*. 2022) that causes rapid drying of the soil around the band (reducing P availability), the low frequency of band re-wetting during a growing season – especially in winter and the very low initial Colwell P values in the surface (0-10cm <18 mg P kg^{-1}) and subsurface (10-30cm <4 mg P kg^{-1}) soils (see Bell *et al*. 2022).

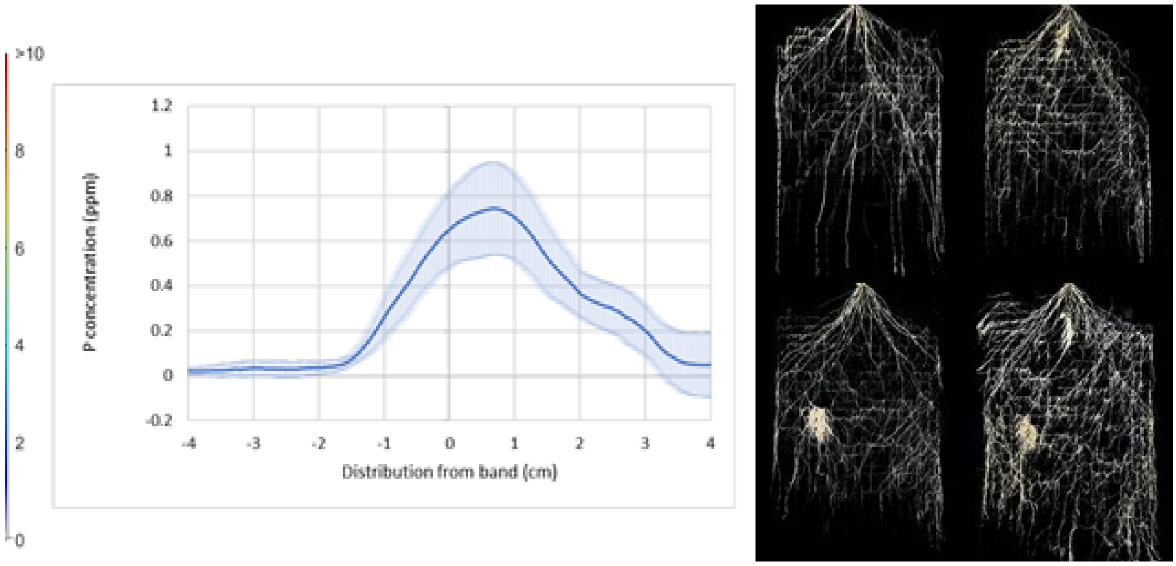

Figure 2. (a) Banded P in Vertosols enriches only small soil volumes in and close to the band, as shown by this net increase in P in diffuse gradient technology (DGT) strips at varying distances from an MAP band (Janke et al. unpublished data). (b). This makes localized root proliferation around each band a critical success factor for accessing that P in these soil types (image from van der Bom et al. 2022).

It has also been demonstrated that the chemical environment in concentrated P bands (i.e., high rates of P and wide band spacings) can limit the amount of extractable P (e.g., Colwell P, or isotopically exchangeable P) in the enriched zone within and around the band. The most important factor driving this effect is pH in the band (the more acidic the pH the lower the proportion of extractable P due to the precipitation of P as Al-P minerals), but soil related factors such as mineralogy (clay content and clay type – Fig. 3) and the addition of other cations (e.g., potassium – K) can also be important (Meyer et al. 2021). These effects can cause the precipitation of applied P as a variety of taranakites and calcium-phosphate minerals (Meyer et al. 2020; Janke et al. 2022 in press), further restricting any likely diffusion of P out into larger soil volumes. The relationship between these soil test measures of extractable P, which collectively suggest reduced P availability in concentrated P bands with and without added K, and the extent to which plants can exploit these P bands over time in the field (e.g., Table 1) are currently under investigation. However, it may be possible for crop roots to slowly access at least some of this precipitated P to support residual benefits in the field.

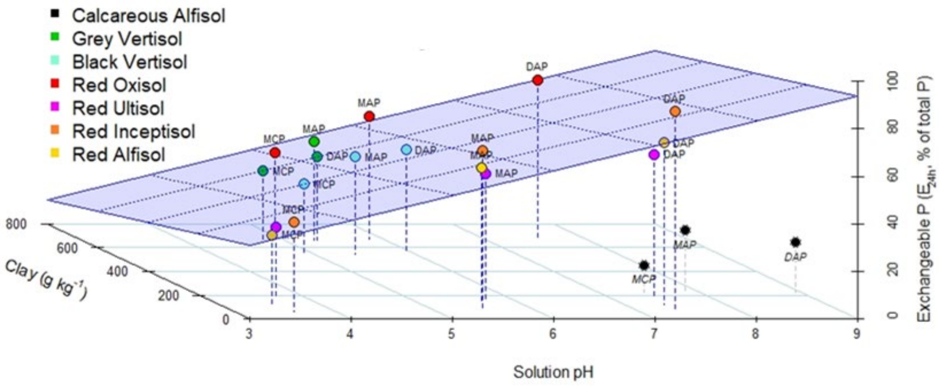

Figure 3. A graph showing the relationship between an estimate of bioavailable P (E_{24h}), pH in the band environment and soil clay content is shown for mono- and di-ammonium P (MAP and DAP) and mono-calcium P (MCP, or triple super phosphate) in a range of contrasting soil types (Meyer *et al*. 2021).

Overall, it is known that deep P bands produce good crop responses in Vertosols in the field. However, there are some factors that seem to be reducing their effectiveness for completely overcoming P infertility, and perhaps resulting in lower-than-desired fertiliser P use efficiency. It is possible that some of these issues may be overcome with time in a deep banding program, by re-application of deep P bands in different places in the field on each occasion, thereby increasing total subsurface P and the frequency of bands. This will progressively enrich a larger soil volume while exploiting the strong residual value of banded P fertilisers in these soils. Given that P decline in northern cropping systems has slowly increased with crop removal over many decades, it is logical to assume that management responses will also take time to halt and/or reverse the P depletion. However, these findings have also raised the question of whether there are other ways to overcome this P availability problem more rapidly.

Mixing fertiliser P through larger soil volumes:

Limited volumes of P enrichment are a characteristic of banded P applications, with implications for the ability of various crop root systems to proliferate and access P from bands. Consequently, there are questions as to whether mixing P Fertilisers through a greater soil volume in a single application may be a more effective way of supplying P. This strategy would likely avoid some of the P precipitation/solubility issues that arise in concentrated bands (Figure 3), but any advantage may possibly be countered by greater interactions between the soil and fertiliser, increasing the exposure of the applied P to adsorption by clay minerals and organic matter. Vertosols are typically considered to have low-moderate sorption capacity, which is a measure of the ability of a soil to retain P on soil particles when it is applied in solution. The soil Phosphorus Buffer Index (PBI) shown in commercial soil tests is a measure of this sorption capacity, and represents the ability of a soil to sorb P in response to a large rate of P addition (1000 mg P kg^{-1}). While differences in PBI between soils reflect differences in P sorption capacity, a more detailed understanding of differences in the dynamics of added P between soil types is needed to understand fertiliser-soil interactions and can be obtained by conducting more labour-intensive P sorption curves such as those shown in Figure 4. Sorbed P can act as a major reservoir of 'stored' P that can replenish soil solution P concentrations. However, understanding the amount of added P needed to 'fill' the reservoir and the rate at which that reservoir can supply P to the soil solution to meet crop demand, requires a more detailed understanding of P sorption processes – especially in Vertosols which have not been extensively studied. Raymond et al. (2022) has recently completed studies demonstrating that while Vertosols as a classification have a number of properties in common, there is still a lot of diversity between Vertosols from different locations. As Sol famously said, 'oils ain't oils' and the same can be said for Vertosols.

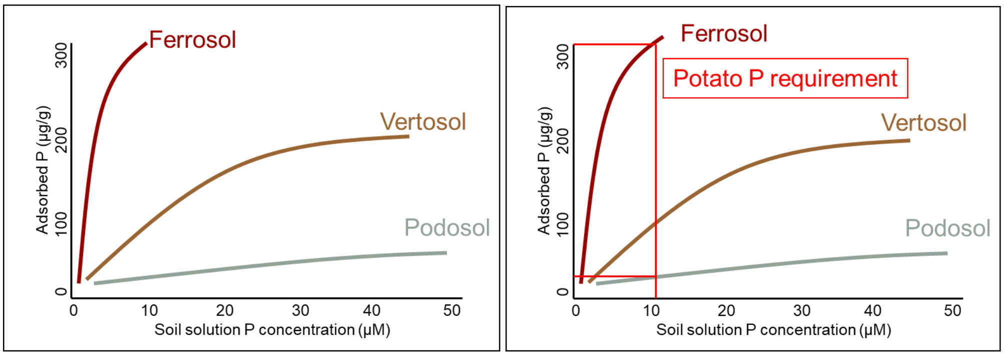

Figure 4. (a) The relationship between soil solution P concentration and the amount of P adsorbed to the soil solid phase for soils with a high (Ferrosol), moderate (Vertosol) and low (Podosol) PBI, and (b) the difference in amount of sorbed P that would be needed in each of these soils to achieve a critical solution P concentration to grow a potato crop. (P Kopittke 2022 - unpublished).

Previous work on the fate of dispersed and incorporated P fertilisers was conducted by Strong et al. (1997) on Vertosols in the western Downs (Billa Billa and The Gums). That work developed a relationship between the amount of P applied (as Triple Super Phosphate [TSP]) and the increase in soil Colwell P at the end of the growing season. This relationship showed that the increase in Colwell P was equivalent to only 29% of the P added in fertiliser, so we used this relationship to establish field experiments with dispersed P on Vertosols at Hopelands and Gindie (both with a PBI of ~120) to define critical topsoil and subsoil P concentrations for different crop species. However, soil tests taken after the initial crop season showed that while the measured Colwell P response was correlated to the P added, the concentrations obtained were less than those targeted, and the relationship varied between sites and profile depths (Figure 5). The Colwell P in the top 10cm layer at Hopelands and Gindie was only 46% (Hopelands) to 59% (Gindie) of that predicted by the Strong et al. (1997) model, and while the subsoil (10-30cm) layer at Gindie behaved similarly to the topsoil (52% of predicted), the subsoil from Hopelands only reached 16% of the targeted Colwell P concentration. The reasons for this were unknown, but these large variations will have a big impact on the efficacy of dispersed P applications and highlighted the need to better understand what drives these differences and how to predict them for different locations.

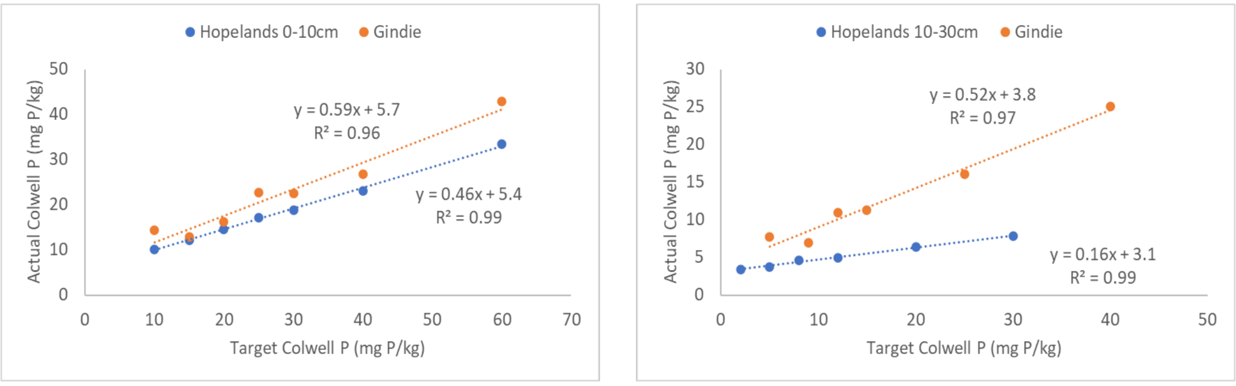

Figure 5. Relationship between Colwell P predicted using the relationship developed on Vertosols at The Gums and Billa Billa (Strong et al. 1977) and the actual change in Colwell P in the 0-10cm (a) and 10-30cm (b) layers in field trials at Hopelands and Gindie. Data from Bell, Lester and Sands – UQ00082 unpublished).

Studies undertaken by Dr Nelly Raymond in the GRDC project UOQ1905 examined the P sorption and desorption characteristics of Vertosols collected from grain growing fields across Qld and NNSW, with a detailed coverage of this work reported in Raymond et al. (2022). Of particular interest was the large variation in sorption characteristics across the Vertosol group (Figure 6a), and perhaps more importantly, the variability in P desorption that can occur after relatively low rates of P addition (Figure 6b). The latter is of particular interest, in that it is a short-term indicator of the ease with which sorbed P can be re-released into the soil solution in response to crop P uptake.

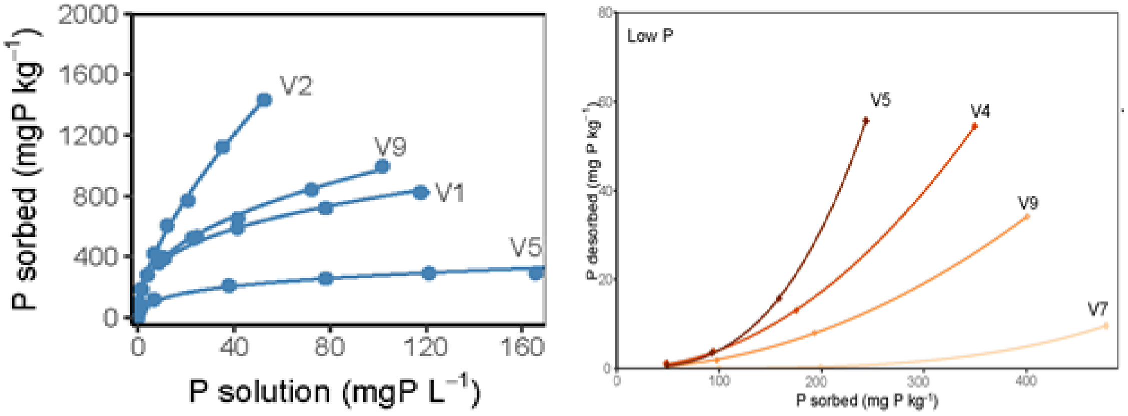

Figure 6. (a) Phosphorus sorption curves for soils collected from the 10-30cm layer of cropped Vertosols, with curves fitted using a non-linear regression model based on a Freundlich equation; and (b) Phosphorus desorption curves for four Vertosols differing in their P release at low concentrations of P initially sorbed (< 500 mg P kg^{-1}; Low P).

These short-term assays reflect the initial interactions between fertiliser P and soil and suggest that despite a relatively narrow range of PBI's (100-200), there are large variations in the sorption capacity and more importantly, in the likelihood of sorbed P from low application rates into P-depleted soils being readily desorbable again in the short term. This low proportion of readily desorbable P reflects a high proportion of vacant P-specific sorption sites which will tightly retain fertiliser P that is mixed through large soil volumes. Interestingly, as the amount of sorbed P increases with increasing P inputs, these P-specific sorption sites become much less prevalent, the fraction of desorbable P increases and differences between Vertosols were much reduced. This suggests that the severity of P depletion is likely to have a large impact on the plant availability of P mixed through large soil volumes and is consistent with the much lower Colwell P observed in the P depleted and unfertilized 10-30cm layers in Figure 5 – especially at Hopelands.

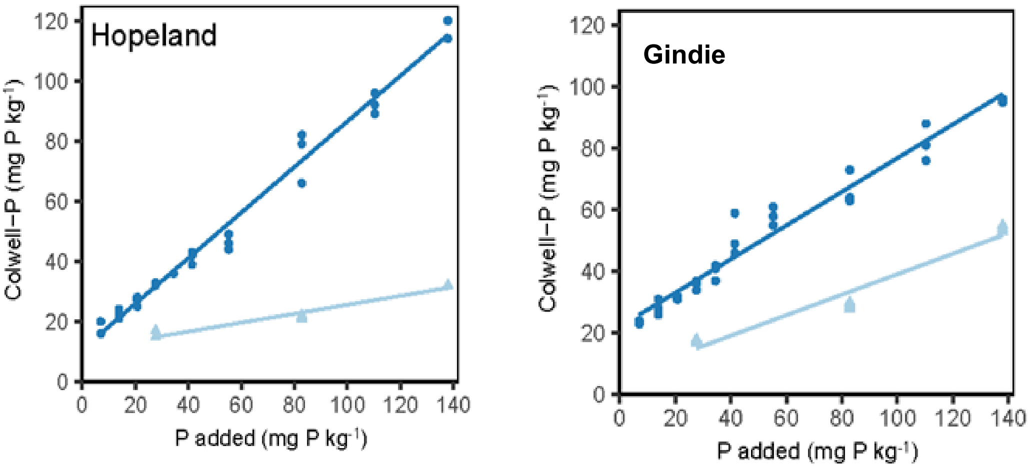

Figure 7. Potentially plant soil available P indicated by Colwell-P following fresh (dark blue line) and aged (light blue line) MAP applications for sites at Hopelands and Gindie. Both were Vertosols with similar PBI (~120), with slightly higher initial Colwell P at Gindie. Raymond et al. 2022 (unpublished)

However, these findings have been derived from short term assays that do not necessarily reflect the longer-term fate of dispersed fertiliser P over time. It is generally accepted that availability of fertiliser P declines with time in contact with soil as a result of processes such as slow diffusion of adsorbed P into surfaces of adsorbing material, P moving into cracks and voids in mineral structures and increased chemical reactions that result in products of low solubility. This is clearly illustrated in Figure 7, which shows the increase in Colwell P immediately after incorporation in topsoils from Gindie and Hopelands and in soils collected from field plots two years after fertiliser application. The drop in Colwell P was much more pronounced in the soil at Hopelands than it was in the Gindie soil, suggesting a lesser long term residual P benefit. The work reported by Raymond et al. (2022) clearly shows that both the initial increase in Colwell P in response to fertiliser application, and the new equilibrium P concentration that results from it, are most closely correlated to the PBI of the soil and the Colwell P concentration prior to fertiliser application. These factors can be combined in an index called the P saturation index (PSI : Colwell P/PBI), with the likely beneficial impact of a dispersed P application decreasing as Colwell P declines or PBI increases. We have not worked with a wide enough range of soils with contrasting PSI values to establish whether this index will be useful in determining the effectiveness of dispersed P applications, but it is reasonable to suggest that all the tested 10-30cm layers would fall in the very low PSI category where dispersed P would be relatively ineffective (i.e., Colwell P <10 and PBI 120-180).

Implications for fertiliser P management in Vertosols:

More effective fertiliser P management is increasingly critical for productive cropping on Vertosol soils in northeast Australia, with inputs into both topsoils (0-10cm) and subsoils (10-30cm) needed to meet P demand under the variable rainfall conditions experienced in these opportunistic cropping systems. Ammonium phosphates are the most effective form of P fertiliser, with little difference in P availability between DAP and MAP. However, the wide range in soil physical and chemical characteristics within this soil type and the highly variable seasonal rainfall will have major implications for fertiliser P management.

Periodic deeper placement is essential to reverse declining fertility in layers that are important sources of P when topsoils are dry, with effective placement in these layers mainly reliant on banding to minimise loss of groundcover, soil tilth and moisture. Trying to disperse P through larger soil volumes with aggressive tillage in these deeper soil layers is likely to be relatively ineffective due to the very low PSI and the high proportion of highly specific P sorption sites that limit P availability to plants. However, if fertiliser bands are too concentrated (e.g., high rates in wide row spacings), root access is limited, and precipitation reactions reduce the proportion of applied P that remains available for plant uptake. The demonstrated residual benefits of banded subsoil P support less frequent applications conducted when moisture conditions are favourable and fertiliser prices are affordable. Closer spaced but less concentrated bands will increase the volume of P-enriched soil and minimize the chance of precipitation reactions within and around the bands. Closer band spacing can be achieved by either closer tine spacing or staggering band positioning during reapplications to treat 'new' soil each time. We have conducted experiments to explore interactions between P rate and band spacing at a single application time, but despite early season NDVI showing narrow bands were giving stronger crop responses, it was ultimately the amount of P applied (rate) that drove yield increases.

In topsoil layers with (generally) higher PSI and fewer vacant P-specific sorption sites, there is a less compelling argument for application of concentrated P bands given the fluctuating soil moisture availability. The exception is starter P applied in or near the seeding trench to enhance early seedling vigour and meet the demands of young plants with small and inefficient root systems, but P application rates are often limited by the nitrogen content in the ammonium phosphate fertilisers on which starter products are typically based and the quantity of P acquired by the plant is normally small. However, while the response to an increased volume of soil P enrichment is likely to be more positive in these surface layers, the P sorption capacity is still sufficient to limit the fraction of fertiliser P recovered by plants. Root access to dispersed P in topsoils will also be highly dependent on seasonal moisture availability and resulting root activity, and so a focus on topsoil P enrichment will provide highly variable seasonal contributions to crop P uptake.

Conclusions

This research is unveiling the complexity and contrast in P behaviours that exists in soils which have nominally similar characteristics of classification and PBI. Deep banding fertiliser P (MAP/DAP) into the 10-30 cm layer remains an effective option to increase plant P availability in Vertosols across the northern grains region. Growers are also encouraged to continue applying starter fertilisers with their crops at sowing.

Enriching large volumes in subsoils (10-30 cm) with dispersed P appears prone to delivering only relatively small changes in plant P availability despite applying high P rates, let alone being relatively impractical.

Research opportunities exist to further understand the nature of these P sorption behaviours in the subsoil, the interactions with multiple bands not only in space but time, and the dynamics of P within the band.

Further reading

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Timing of flowering and pod initiation influences yield potential in chickpeas

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Key words

chickpea, early flowering, yield, phase development, chilling tolerance

GRDC code

BLG111

Take home messages

- Chickpeas are sensitive to average temperatures of less than 15°C during flowering, which causes flower abortion
- Early flowering does not equal early pod set or increased grain yield
- Sow within the recommended cultivar window to ensure that the majority of flowering occurs when temperature conditions are optimal
- Understanding developmental phase changes can improve productivity by aligning flowering and podding with optimal temperatures for a given environment.

The story so far

Chickpeas are suited to environmental conditions of many grain growing regions of Australia and are an important winter pulse crop for farming systems. Despite this, in northern NSW and southern Queensland, abiotic and biotic factors are estimated to cause yield reductions of 1.7 – 2.7 t/ha (Yield Gap Australia, 2018). In 2016, cool spring weather was estimated, to have resulted in yield losses of 0.5 – 0.7 t/ha in northwest NSW (K. Hobson, *pers. com.*).

Under ideal environmental conditions, chickpea will produce pods within a couple of days of flowering (Clarke & Siddique, 1998). However, if temperatures stay below optimal levels the length of time between the beginning of flowering and the commencement of podding can be more than two months (Berger *et al*., 2005). Furthermore, if average daily temperatures are below 15°C during flowering, there is reduced pollen viability, delayed stigma development and flower drop as reported by Siddique and Sedgley (1986) and Srinivasan *et al.* (1999). They observed that average temperatures during flowering significantly influenced flower abortion. Siddique and Sedgley (1986) found that when chickpeas were sown early and experienced average temperatures of 12.5°C during flowering there was 800 aborted flowers/m^2, compared to 0 aborted flowers/m^2 from a later sowing date where the average temperature was 16.8°C during flowering.

How did we get here?

In 2020, detailed phenology experiments were conducted at Tamworth in northern NSW and Wagga Wagga in southern NSW. In this series of experiments, sowing time was used to assess the capacity of a range of genotypes to produce pods and seeds under cool temperatures. These experiments included a set of 12 diverse genotypes, both released cultivars and advanced breeding lines, and targeted three sowing windows, with an early (late April to early May), main (mid-May to early June) and late season (mid to late June) sowing. Plant phasic development stages, between late vegetative and pod initiation were defined and dates were recorded. Changes in phase development that are important for pod and seed development under suboptimal environmental conditions included; the date when plants become reproductive, the date when 50 % of plants have one open flower and the date of pod initiation.

What did we find?

Phenology responses – flowering and pod initiation

Sowing date and location were found to influence the timing of phasic development of individual genotypes. At Tamworth, from the early sowing, in late April (Figure 1), the early flower CBA line had at least one flower on 50% of plants by 28 July, 22 days earlier than the next cultivar, CBA Captainⓓ and 35 days earlier than the slowest variety Kyabraⓓ. When sown in late April, Kyabraⓓ flowered on 1 September, 2 days before the average air temperature rose above 15°C on 3 September (Figure 1). In contrast, when the cultivars were sown in the optimal/main sowing window in late May, the early flower CBA line commenced flowering on 29 August, with CBA Captainⓓ and PBA Strikerⓓ achieving 50 % flowering on 5 September, and Kyabraⓓ and PBA Seamerⓓ flowering on 8 September (Figure 1).

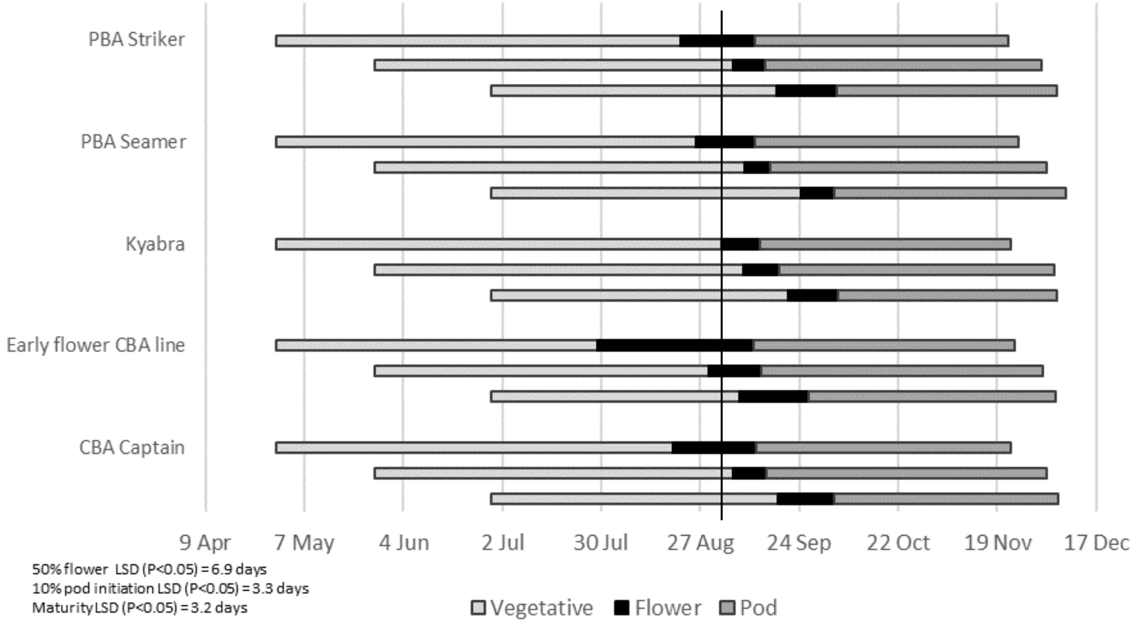
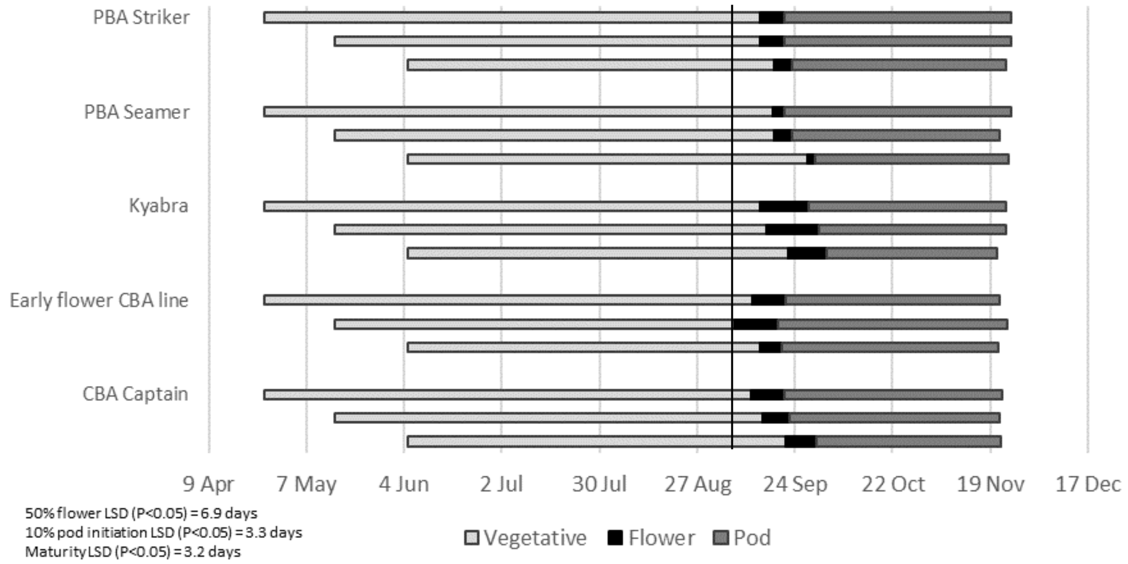


Figure 1. Phase development of four commercially released cultivars and an early flowering genotype at Tamworth in 2020 for three sowing dates. Vertical line represents the date at which average air temperature rose above 15°C on 3 September.

In contrast to the Tamworth findings, flowering did not commence at Wagga Wagga until 6 September, the day the average air temperature rose above 15°C for the first time (Figure 2). The first line to flower from the main sowing in mid-May was the early flower CBA line. Time to flowering was condensed over the three sowing dates (Figure 2 and Figure 3). Date of pod initiation at Wagga Wagga was also condensed, with a small but significant delay in pod initiation for Kyabraⓓ when compared to the early flower CBA line at each of the sowings (Figure 2).



50% flower LSD ($P<0.05$) = 6.9 days
10% pod initiation LSD ($P<0.05$) = 3.3 days
Maturity LSD ($P<0.05$) = 3.2 days

Figure 2. Phase development of four commercially released cultivars and an early flowering genotype at Wagga Wagga in 2020 at three sowing dates. Vertical line represents the date at which average air temperature rose above 15°C on 6 September.

Pod initiation, averaged over all genotypes at Tamworth for late April, late May and late June sowing dates, respectively, occurred 10, 13 and 32 days after average air temperature became optimal (3 September) (Figure 1). The delay in pod initiation, for the late June sowing at Tamworth, reflected the dry spring and depleted soil moisture in dryland cropping systems in northern NSW in 2020.

In contrast, when averaged over all genotypes, at Wagga Wagga, pod initiation for the late April, mid-May and early June sowings, respectively occurred 16, 18 and 25 days, after optimal average air temperature was achieved on 6 September, (Figure 2). Pod initiation at Wagga Wagga was in part delayed due to the higher level of temperature fluctuation in September, when temperatures rose and fell, above and below the optimal average air temperature of 15°C.

The relationships between date of 50 % flowering and date of pod initiation varied between the two sites (Figure 3). Genotypes sown early at Tamworth, had a spread of dates for the time to 50% flowering between 19 July to 9 September (52 days), while pod initiation occurred quickly, from 9 September to 13 September (4 days) (Figure 3). In comparison, the second and third sowing dates both had a variation in the time to 50% flowering of 17 days and 20 days, while pod initiation was spread over 9 days and 12 days, respectively (Figure 3).

The relationships between date to 50 % flowering and date of pod initiation, were compressed at Wagga Wagga when compared to Tamworth (Figure 3). There was overlap of both the date to 50% flower and the date of pod initiation between the three sowing times (Figure 3). Early and main sowing had similar dates to 50 % flowering from 7 September to 18 September and pod initiation from 14 September to 6 October. It is surmised, that this compression of dates for these phenological stages, may have been due to the greater variation in spring temperatures observed at Wagga Wagga, when compared to Tamworth.

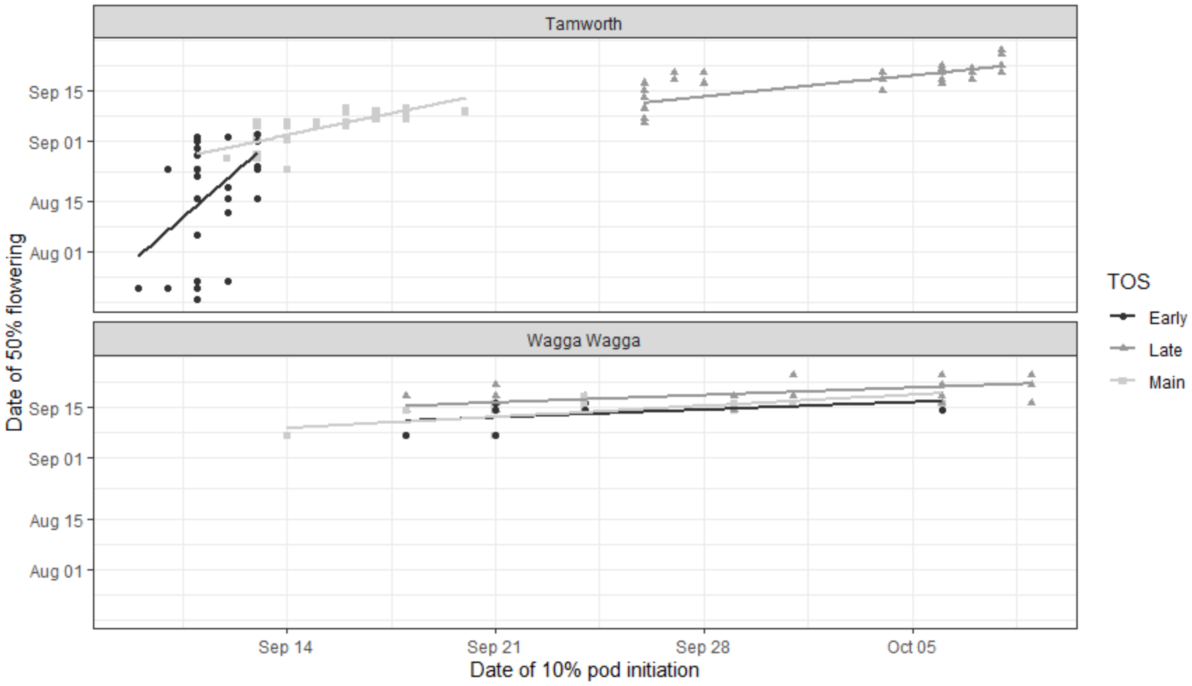


Figure 3. Relationship between date of 50% flowering and the date of pod initiation at Tamworth and Wagga Wagga in 2020.

Indictive yield response

When pooled across all genotypes, highest grain yield was observed when crops were sown between mid to late May, yielding 2.5 t/ha at Tamworth and 2.7 t/ha at Wagga Wagga (Figure 4). Sowing earlier than mid-May caused a yield loss of approximately 7 % at Tamworth and 18 % at Wagga Wagga (Figure 4). In part, the lower grain yield associated with early sowing, may be due to the longer time spent during the reproductive period in suboptimal temperatures.

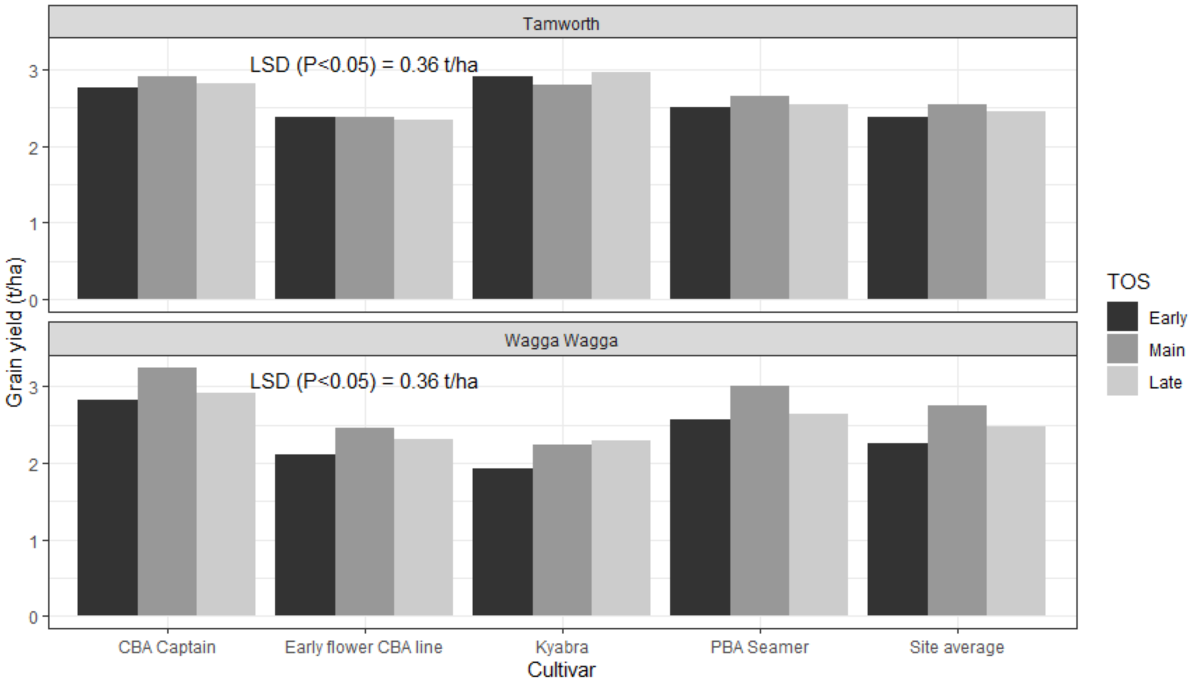


Figure 4. Grain yield (t/ha) for selected varieties and site average at Wagga Wagga and Tamworth for the three sowing dates in 2020.

Individual varieties showed different patterns of yield rankings over the three sowing dates at both Wagga Wagga and Tamworth. Differences in yields between the three sowing dates for four genotypes, CBA Captainⓓ, early flower CBA line, Kyabraⓓ and PBA Seamerⓓ, at Wagga Wagga were significant, whilst at Tamworth they were not. When each of the four genotypes were sown early at Wagga Wagga there was a reduction in yield of between 12 % to 14 %, when compared to their main season sowing yields (Figure 4).

This loss in grain yield when crops were sown earlier than optimal can be partially explained by plants developing flowers that do not form pods or pods with seeds when temperatures are suboptimal. Current research, within this project, aims to look at the level of lost flowering opportunities and potential pods and seeds, when crops flower under suboptimal conditions, through measuring the conversion of reproductive nodes into pods and pods that contain seeds.

Summary

Matching developmental phases, in particular flowering and pod initiation to optimal environmental conditions increases the yield potential of chickpea cultivars. Importantly, results from these experiments show that early flowering does not translate to earlier pod initiation. This was particularly highlighted when comparing genotypes from an early sowing date at Tamworth in 2020.

The results from these experiments do however indicate that there is greater variation in pod initiation between genotypes from main and late season sowings, with earlier flowering genotypes initiating pods earlier than later flowering lines.

It can be seen from these experiments that early flowering does not equal early pod initiation or increased grain yield.

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