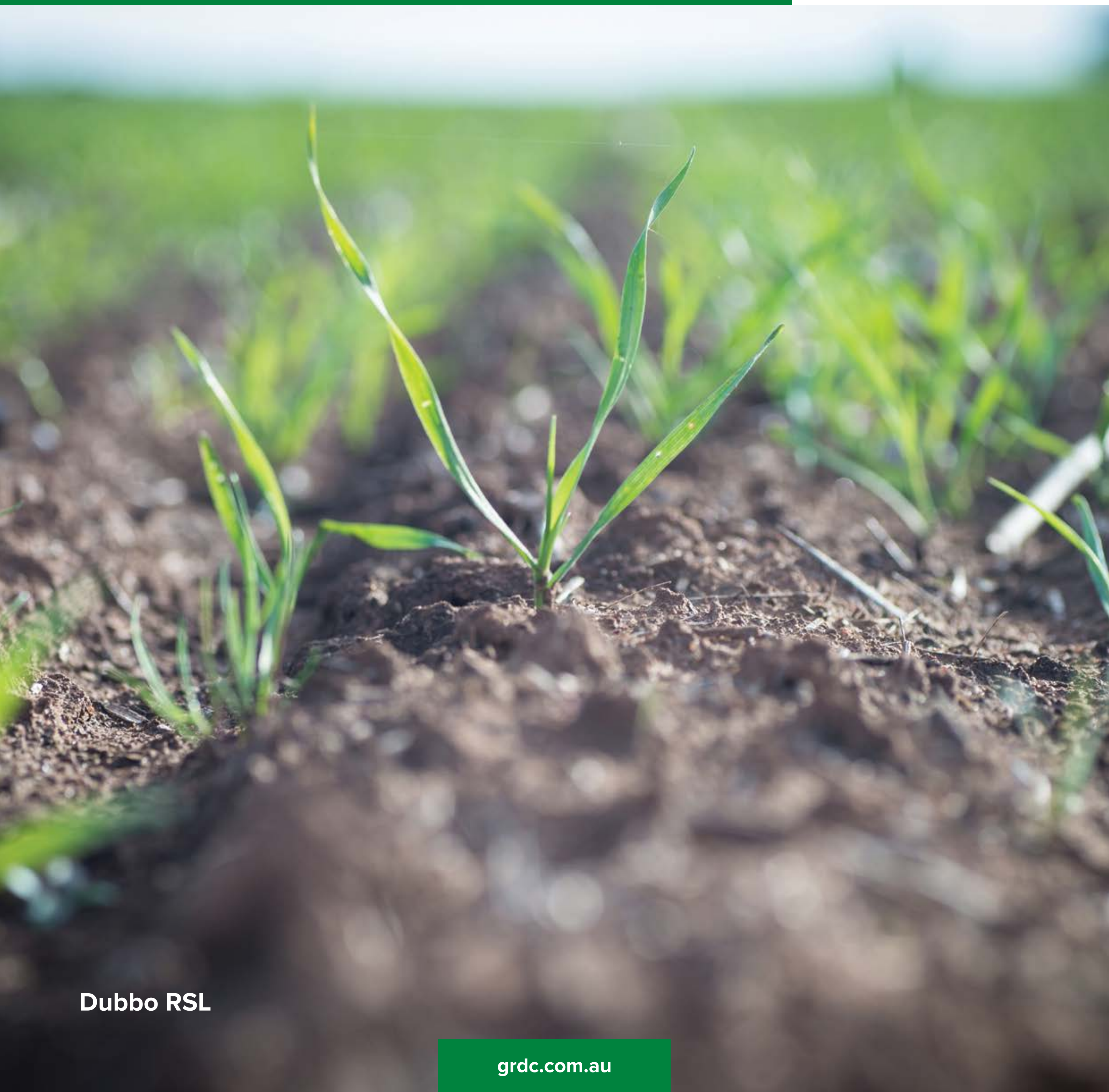
DUBBO
NEW SOUTH WALES
TUESDAY 25 AND WEDNESDAY 26 FEBRUARY 2020

GRAINS RESEARCH UPDATE

DRIVING PROFIT THROUGH RESEARCH

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION



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GRDC 2020 Grains Research Update Welcome

If you are reading this, then chances are you have taken time out from an extraordinarily tough season in our very sunburnt country to hear the latest grains research, development and extension (RD&E) information.

Welcome.

We at the GRDC understand how very challenging the current situation is for growers, advisers, agronomists, researchers and those associated with the grains industry across New South Wales and Queensland.

Drought takes an enormous toll financially, emotionally and physically on those working and living through it daily. We trust that these GRDC Grains Research Updates will offer you new research information to help guide your on-farm decisions this season and to be best placed to take advantage of future seasons. We also hope the Updates provide a chance to connect with your peers and temporarily escape work pressures.

We would like to take this opportunity to thank our many research partners, who, like growers and advisers, have gone over and above in recent years to keep trials alive in rain-deprived environments.

Challenging seasons reinforce the importance of rigorous, innovative research that delivers genuine gains on-farm. 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 Updates, which are the premier event on the northern grains industry calendar and bring together some of Australia's leading grains research scientists and expert consultants.

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.

For the past four years we have been doing that from regional offices across the country. Through the northern region offices in Wagga Wagga and Toowoomba and a team of staff committed to connecting with industry, we are now more closely linked to industry than ever.

Today, GRDC staff and GRDC Northern Panel members are at this Update to listen and engage with you. This is a vital forum for learning, sharing ideas and networking, all of which are critical to effect successful change and progress on-farm.

Regards,
Gillian Meppem
Senior Regional Manager North

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GRAINS RESEARCH UPDATE

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PROGRAM DAY 1 – TUESDAY 25 FEBRUARY 2020

Time	Topic	Speaker (s)
9:00 AM	**Registration, morning tea and trade displays**	
10:00 AM	**Welcome**	***GRDC***
10:15 AM	**A look into the future -** Australia's grains industry in 2030	***Prof. Ross Kingwell*** *(AEGIC)*
10:45 AM	**New chemistry -** what's new, what's coming and how do we keep them for longer?	***Greg Condon*** *(Grassroots Agronomy/AHRI)*
11:15 AM	**Is our ryegrass really getting harder to kill through our over reliance on glyphosate? & Water quality impact on phenoxy efficacy**	***Maurie Street*** *(GOA)*
11:40 AM	**NVT online -** robust, reliable variety selection decisions	***Laurie Fitzgerald*** *(GRDC)*
12:00 PM	Lunch	
1:00 PM	**Concurrent session 1** *(See concurrent sessions for details)*	
2:45 PM	Afternoon tea	
3:15 PM	**Concurrent session 2** *(See concurrent sessions for details)*	
5:00 PM	Close	
5:05 PM	**Emerging Agronomists Networking event - further information and registration can be found at www.seedbedmedia.com.au/agronomists** *Note: Separate registration is required to the Update*	
7:00 PM	**Stand-up networking event, Devil's Elbow Brewery** *10 Commercial Ave Blueridge Business Park, Dubbo NSW 2830 (Supported by Syngenta & AGT)*	

PROGRAM DAY 2 – WEDNESDAY 26 FEBRUARY 2020

Time	Topic	Speaker (s)
7:30 AM	**Early risers - Panel session on cereal and pulse pathology after the drought; evaluating risk after crop and pasture; what's new (seed treatments); Predicta® B for in-crop diagnostics; options for high risk paddocks** *Discussion led by* ***Steven Simpfendorfer*** *(NSW DPI) and* ***Kevin Moore*** *(NSW DPI)*	
8:30 AM	**Concurrent session 3** *(See concurrent sessions for details)*	
10:15 AM	Morning tea	
10:45 AM	**Concurrent session 4** *(See concurrent sessions for details)*	
12:30 PM	Lunch	
1:30 PM	**Lasers, machine learning, weed recognition software and new innovations in weed management.**	***Caleb Squires*** *(USyd)*
1.55 PM	**Herbicide approval processes -** they can be relied on!	***Jason Lutze/Sheila Logan*** *(APVMA)*
2:25 PM	**Discussion forum -** Q & A dealing with the drought and planning for recovery	***Simon Fritsch*** *(Agripath),* ***Garry Littlejohns*** *(AMPS Commercial) &* ***Roger Todd*** *(Wirrinun Pastoral Co)*
3:00 PM	Close	

LOCATION & TIMING OF CONCURRENT SESSIONS

	Theatrette	Starlite 1 & 2	Starlite 3
Day 1 Sessions 1 & 2	Soil water and health	Farming systems	Consulting
Day 2 Session 3 & 4	Nutrition	Agronomy	Dual purpose crops

CONCURRENT SESSIONS

Soil water and health (Day 1, sessions 1 & 2)

Time session 1	Time session 2	Topic and Speaker (s)
1:00 PM	3:15 PM	**Risks and rewards of cover cropping -** how effective are cover crops at increasing fallow efficiency and influencing soil health? ***Colin McMaster*** *(NSW DPI)*
1:30 PM	3:45 PM	**Implications of acid soils for crop sequencing -** innovative approaches to sub-soil liming and management ***Guangdi Li*** *(NSW DPI)*
2:00 PM	4:15 PM	**Predicting and mapping soil properties and their yield impact**. Paddock scale soil mapping to explain yield variability - combining yield data, NDVI, Dual EM, gamma radiometrics, elevation, and soil colour to select sampling sites and then predict soil properties and their impact on yield potential across the paddock ***Pat Hulme*** *(Sustainable Soils Management) &* ***Ed Jones*** *(University of Sydney)*
2:30 PM	4:45 PM	**PhD Presentation -** Improving Phytopthora root resistance in chickpeas through breeding for tolerance to waterlogging - shorter term implications for diagnosing root health and timing of Predicta®B tests ***Nicole Dron*** *(NSW DPI)*

Farming systems (Day 1, sessions 1 & 2)

1:00 PM	3:15 PM	**Nitrogen, water and disease in the farming system -** the multi-year impact of crop sequences ***Greg Brooke*** *(NSW DPI) &* ***Lindsay Bell*** *(CSIRO)*
1:35 PM	3:50 PM	**System profit and commodity price risk -** impact of varying commodity prices on farming system profit and risk ***Lindsay Bell*** *(CSIRO)*
2:05 PM	4:20 PM	**Implications for crop sequencing decisions** - how we manage water, nutrition and disease; decisions in 2020 on soil water and crop sequence. *Discussion session led by* ***Glenn Shepherd*** *(IMAG Consulting) &* ***Graeme Callaghan*** *(Delta Agribusiness) in session 1 and* ***Matt Shephard*** *(IMAG Consulting) &* ***Mick Harris*** *(AGnVET Services) in session 2*

Consulting (Day 1, sessions 1 & 2)

1:00 PM	3:15 PM	**Warning signs that you or your clients are suffering and more than stressed -** what can you do? ***Camilla Kenny*** *(RAMHP)*
1:40 PM	3:55 PM	**Resilient and trusted adviser/grower relationships -** technical knowledge is only half the story! ***Dennis Hoiberg*** *(Lessons Learnt Consulting)*

Nutrition (Day 2, sessions 3 & 4)

Time session 3	Time session 4	Topic and Speaker (s)
8:30 AM	10:45 AM	**5 years of nitrogen research -** do we have the system right? - N movement, use efficiency, application timing & impact on N uptake - should we fertilise the system or the crop? - N in pulse crops? - N impacts on screenings ***Richard Daniel*** *(NGA)*
9:00 AM	11:15 AM	**Fixing more N by improving inoculant performance in suboptimal conditions** ***Belinda Hackney*** *(NSW DPI)*
9:30 AM	11:45 AM	**What N is in profile - 3 dry years with minimal mineralisation.** What are the results showing? Also insights from a long-term nutrition site running since 2007 in CNSW ***Jim Laycock*** *(Incitec Pivot)*
10:00 AM	12:15 PM	**Nutritional decision making for 2020** *Discussion led by* ***Mike Bell*** *(UQ),* ***Richard Daniel*** *(NGA),* ***Jim Laycock*** *(Incitec Pivot) &* ***Belinda Hackney*** *(NSW DPI)*

Agronomy (Day 2, sessions 3 & 4)

8:30 AM	10:45 AM	**Maintaining wheat yield & quality under high temperatures -** how do current cultivars compare with what's coming? ***Rebecca Thistlethwaite*** *(USyd)*
9:00 AM	11:15 AM	**Practical applications for earlier sowing of cereals -** how does it work in central NSW? ***Greg Brooke*** *(NSW DPI)*
9:30 AM	11:45 AM	**Drivers of yield stability in wheat and barley -** picking a winner in variable seasons ***Felicity Harris*** *(NSW DPI)*

Dual purpose crops (Day 2, sessions 3 & 4)

8:30 AM	10:45 AM	**Integrating livestock into cropping systems -** agronomy, dry matter production, time of sowing & nutrition ***Peter Matthews*** *(NSW DPI)*
9:00 AM	11:15 AM	**Paddock layout, fencing, water and grazing management in dual purpose crops** ***David Harbison*** *(DR Agriculture)*
9:30 AM	11:45 AM	**Dual purpose crops -** direct and indirect contributions to profit ***Lindsay Bell*** *(CSIRO)*
9:55 AM	12:10 PM	**Pro's and con's of grazing -** ground cover, risk, weeds, disease, profit. The role of IWM and making hay or silage. Practical strategies - how will they differ between regions. The consultants perspective for central NSW *Discussion led by* ***Ed Blackburn*** *(Cudgegong Rural Supplies) &* ***Ryan Pratten*** *(MPAC)*

Contents

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Australia’s grains industry in 2030 - a look into the future

Professor Ross Kingwell, Australian Export Grain Innovation Centre

Keywords

grains industry, strategic analysis, grain markets, competition

Take home message

- The grains industry NSW and Vic will experience important structural change towards 2030
- Farmers are likely to increase their commercial dependence on grain storage, feed grain production and domestic market opportunities
- The constant challenge of a warming, drying climate is likely to limit winter crop yield growth in all winter crop regions of Australia and will increase the dependence of extensive livestock production (sheep, cattle, dairy) on supplementary grain feeding.

Background

Dorothea Mackellar’s famous poem, My Country, sums up Australia as a land “of droughts and flooding rains”. Her assessment, written over a century ago, remains apt. Australia’s environmental extremes of drought, flood and bushfire continue to seriously disrupt Australian agriculture, affecting livestock and grain production, and lessening exports of agricultural commodities. Also largely unchanged is the familial basis of farm production in Australia. Yes, farms are larger; yes, there is greater mechanisation; yes, there are fewer farm families but nonetheless the majority of grain, sheep and wool production still comes from farm families who pass down through their generations; their farm business wealth, knowledge and skill in farming.

But many other things are changing to affect greatly or gradually farm production, especially grain production, in Australia. The list of factors includes:

(i) Technological change. Long gone from Dorothea Mackellar’s era is the vital role of horses in crop production. Now, powerful machinery with in-built precision and intelligence aid the sowing, spraying and harvesting of crops. Bulk-handling underpins most aspects of crop production. Communication, commercial transactions, information receival, record-keeping and various types of analysis are now based around computers and mobile phones.

(ii) New crops and changing crop mixes. The wheat-sheep belt, the mainstay of Australian agriculture, has switched its land use to favour more crops, with greater crop diversification. Canola, chickpeas, lentils and lupins, once virtually unknown crops, have emerged to be important components of cropping systems in different regions. The swing into greater reliance on crop revenues is evidenced by Australia’s sheep population shrinking to now being as small as it was in 1905, 115 years ago. Yet, by contrast, in 1905 in Australia 1.5mmt of wheat was produced from 2.5mha compared to 15.9mmt being grown on 10.1mha in 2019.

(iii) Altered soil management. Traditionally fields were ploughed repeatedly to combat weeds to form a friable seed bed. However, the advent of conservation agriculture (Kingwell et al., 2019) now sees crops established in single pass operations, with minimal soil disturbance, increased reliance on herbicides and increasingly with weed seed management at harvest.

(iv) A changing climate. Grain production in Australia is based on rain-fed farming systems. Hence, temporal and spatial changes in rainfall and temperatures crucially affect national crop production. Investigations of long-term weather records reveal a warming trend that is affecting

Australian grain production. Winter crop regions, especially in WA, additionally are affected by a downward trend in growing season rainfall, while on the eastern seaboard, there has been a change in rainfall distribution, with a trend to less rain in winter and more in summer. Extreme heat during grain filling poses a further problem in some regions where farmers observe occasional 'heat frosts' with grain yield and grain quality being adversely affected.

(v) An altered role of government. Traditionally, government played a major role in Australia's grain industry. Rail systems were owned and operated by state governments. Statutory grain marketing was ubiquitous. Research and advisory services were funded and supplied principally by state governments, with the commonwealth government playing an important collaborative role in research funding. Provision of new plant varieties was almost solely the province of State government agencies, universities and the CSIRO. Governments were important employers in many rural towns. Yet now, the march of privatisation, the lesser relative economic contribution of agriculture and the emergence of other claims on the public purse (e.g. natural disaster relief, environmental protection, health and social welfare) have altered the role of government in the farm sector. Increasingly grain farmers pay fully or in large part for advice, grain marketing, research services and grain transport.

Privatisation has not only affected government services. Even farmers' ownership of the key services of grain handling and storage has passed into private ownership (GrainCorp, Viterra). Cooperative Bulk Handling in WA is a key exception.

(vi) Emergent low-cost overseas competitors. Over the last few decades, a seismic shift in grain export prowess and rankings has occurred. In previous decades North America, Europe and Australia were main grain exporters. However, first South America (i.e. Brazil and Argentina) and then the Black Sea region (Russia, Ukraine and Kazakhstan) have greatly increased their grain production and grain exports. AEGIC have released reports on several of these grain exporters (e.g. Kingwell et al., 2016a, 2016b; Kingwell and White, 2018). Russia has replaced the USA as the world's main exporter of wheat. Argentina and Brazil are main export suppliers of feed grains (soybean and corn).

All these changes, in combination, affect the current and future potential of grain production in Australia. Drawing on these changes and other key influences, the next section outlines a possible future for Australia's grains industry at 2030. The ramifications for the grains industry in NSW and Vic are highlighted.

Australia's grain industry towards 2030

Late last year AEGIC released a report (Kingwell 2019) that describes the likely situation and outlook of Australian grain production towards 2030. Similarly, in late 2019 Rabobank examined strategic trends in Australia's grains industry and came to a similar conclusion that, towards 2030, feed grain demand and supply will increase in prominence in Australia, especially in eastern Australia. Any interested readers can read the full report, but for now, the report's following key findings are highlighted below.

Key findings

- Australia's population is projected to increase by between 16% and 19% by 2030. This means between 4.07 and 4.89 million additional people in Australia.
- Little increase in the area sown to winter and summer crops in Australia has occurred since the mid-2000s and further increases are unlikely towards 2030.

- Despite plant breeding, agronomic and technology improvements, the average rate of crop yield improvement is only 0.6 per cent per annum since the late 1980s. There is spatial variation in yield improvement trends and yield volatility remains large in eastern Australia.
- Climate change and seasonal variation are limiting yield growth in many grain-growing regions.
- The mix of crops grown across Australia is fairly stable with a slight increase in the relative importance of canola over the last decade. In eastern Australia, coarse grains and pulses feature more in the crop mix.
- The pattern of meat consumption among Australians is changing, with a growing dominance of chicken and pork consumption at the expense of beef and lamb.
- Increasingly, the main meats consumed by Australians are from grain-fed animals.
- By 2030 in Australia:
  - (i) Feed grain demand will increase by between 2.24mmt and 2.48mmt
  - (ii) An additional 0.64 to 0.77mmt of grain will be required for flour and malt production
  - (iii) An additional 5.65mmt of grain will be produced, increasing from current production of 49mmt in 2017/18 to 54.6mmt
  - (iv) The surplus of grain available for export is expected to be between 2.4 and 2.8mmt
  - (v) Almost all the additional grain production in eastern Australia will need to flow to the east coast domestic market to satisfy its growth in feed and food demand
  - (vi) The main sources of additional exportable surpluses of grain will be WA and SA
  - (vii) The grain quality profile of Australia's main export crop, wheat, is likely to alter, as WA's and SA's share of national wheat exports increases.

A key implication of these findings is that towards 2030, Australia's domestic requirements for grain will become increasingly important, especially in eastern Australia where most of the population increase and greater demand for feed grains, flour, oil for human consumption and malt will occur. By contrast, most of the exportable surpluses of grain will increasingly come from the less populous states of WA and SA.

The task of finding export markets for the additional 2.4mmt to 2.8mmt of export grain available by 2030 may not be overly challenging, given the projected increase in grain imports envisaged for many of Australia's current overseas grain customers. Nonetheless, it needs to be noted that this task of selling more Australian grain will occur against the backdrop of burgeoning exports from low-cost international competitors previously mentioned.

Assuming crop production in Australia towards 2030 remains seasonally volatile, whilst the east coast domestic demand for grain increases in relative importance, then farmers and grain users are likely to react by:

(i) Investing in more grain storage; especially whilst interest rates are low that make the cost of carrying grain affordable

(ii) Focusing more on domestic market opportunities, especially in eastern Australia

(iii) Focusing more on feed grain production, especially in eastern Australia and also possibly in the adjacent state of SA

(iv) Opportunistically selling grain from SA and WA to end-users in eastern Australia, when low production occurs on the east coast. However, this will adversely affect SA's and WA's reputation as reliable exporters to overseas' consumers

(v) Looking more closely at grain supply security when investing in export-focussed grain processing/animal protein industries – with access to export parity grain rather than exposure to import parity on the east coast.

Implications for Vic and NSW grain producers

Although the increased demand for feed grains in eastern Australia may encourage more Victorian and NSW grain producers to alter their crop mix towards more feed grain production, it is unlikely that most farmers will additionally allocate more land to cropping rather than sheep production. Despite the sizeable reduction in the national sheep population since the early 1990s, NSW and Vic farmers have maintained their investment in sheep since the early 2010s (Figure 1).

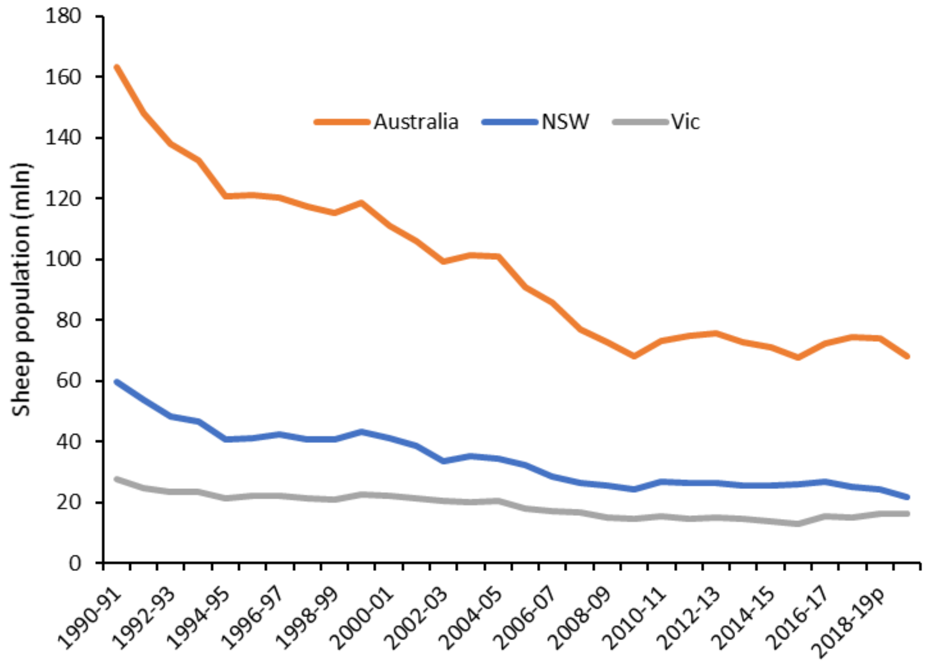

Figure 1. Sheep population in Australia, NSW and Vic since 1990

In order to retain sheep numbers, either pasture areas need to be allocated for sheep production, increased areas sown to dual-purpose crops, or affordable feed grains always need to be readily available. Given the strong upward movement in sheep meat and wool prices over the last several years, on a gross margins basis, farmers are unlikely to switch land and other resources away from sheep production. Moreover, as the domestic and overseas demand for sheep meat and wool continues to expand, then retention of sheep in farming systems is increasingly likely. In addition, retaining sheep provides a means to add value to feed or downgraded grain produced on a farm. Currently, sheep enterprises form a profitable, risk-diversifying role for many farm businesses. As a result, crop production growth will be based largely on yield increases rather than crop area increases. Accordingly, crop breeding and crop agronomy will play crucial roles in ensuring gains in crop production in NSW and Vic.

In coming decades, the traditional flow of grain from Vic and NSW farms down to ports for overseas export could be a less dominant feature of their crop production, as east coast demand for grain increases in relative importance; and especially in years of low production in eastern Australia. Interstate grain flows from SA could also feature more frequently. SA’s small domestic market and more reliable climate for grain production will facilitate grain flows into NSW and Qld. These grain flows however, will affect the returns from owning infrastructure (trains, port terminals, port storage) required for grain exported overseas from NSW, Vic and SA.

As an illustration of how reduced east coast grain production can affect national grain flows, consider the impact of the 2018 drought in eastern Australia (Figure 2) on grain production, domestic consumption (Figure 3) and grain flows (Figure 4).

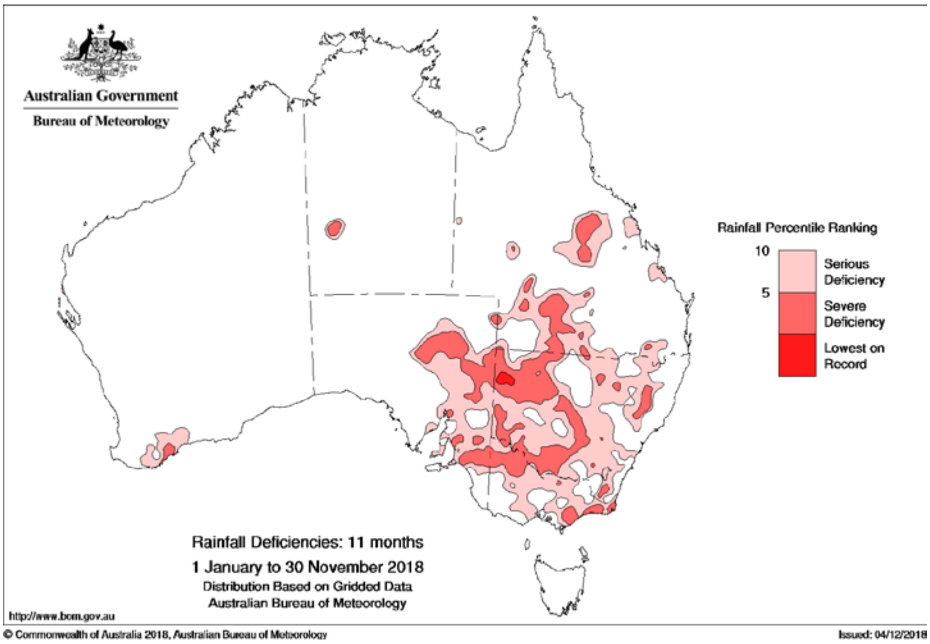

Figure 2. Rainfall deficiencies across Australia in 2018 (up until Nov 30)

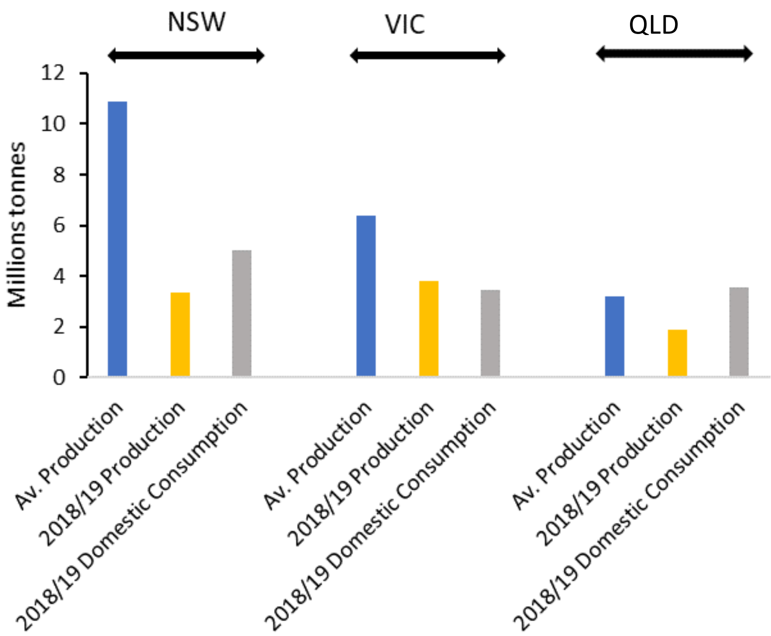

Figure 3. The impact of the 2018/19 drought: NSW, Qld and Vic became grain importers. Source: Based on data in an appendix in ACCC (2019) Bulk grain ports monitoring report 2018–19, Canberra

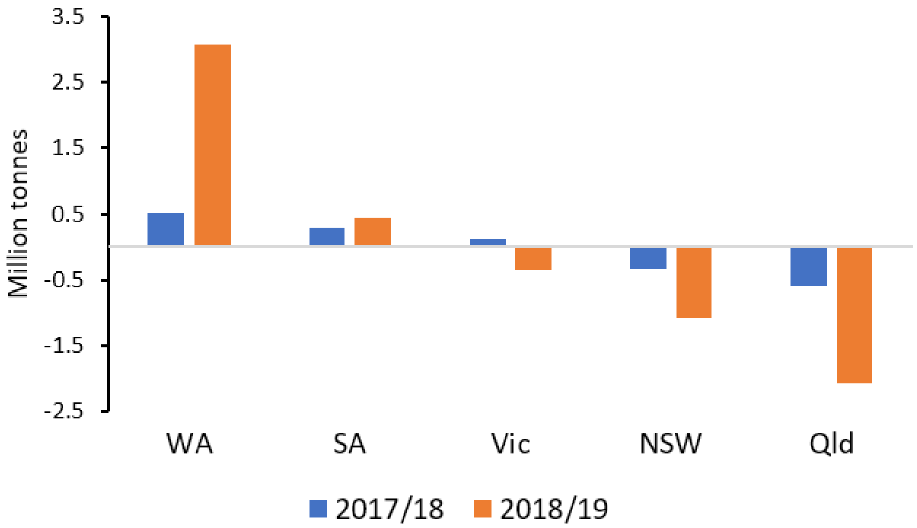

Figure 4. Coastal shipping flows of grain from or into each State in 2017/18 and 2018/19
Source: Based on data in an appendix in ACCC (2019)

In 2018/19 some regions in SA were also affected by drought. The SA grain harvest was only around 5.6 mmt, of which the main grain handler and exporter, Glencore, only exported around 2.6 mmt, indicating that around 3 mmt was either stored, used locally or exported to eastern Australia. Hence, due to SA's small domestic market, even in low production years, SA is able to capitalise on favourable market opportunities in eastern Australia.

In years when SA or WA escape drought, yet eastern states are drought-affected, then sizeable interstate grain flows from these states are likely. Freight differentials in coming decades could be further affected by construction of the inland rail in eastern Australia, due for completion in 2025. If the inland rail is sufficiently cost-effective, then interstate grain flows from SA could be much enhanced in some years. In addition, construction of additional grain port infrastructure in SA will facilitate coastal trade. In eastern Australia, south to north flows of grain by rail, road and ship are likely to become increasingly important towards 2030 as a product of climate volatility and continuing growth in the east coast demand for grain.

The constant challenge of a warming, drying climate is likely to limit winter crop yield growth in all winter crop regions of Australia and will increase the dependence of extensive livestock production (sheep, cattle, dairy) on supplementary grain feeding. Simultaneously, further population growth, especially in the eastern states, will increase the national market demand for grains, especially feed grains. The corollary is that growth in grain production in Australia is likely to be modest and the tendency will be for a growing proportion of grain to flow to domestic markets. Exports of grain from NSW and Vic are likely to be constrained by the growth in the Australian domestic market and the constraints of climate trends on crop yields. Depending on seasonal conditions in eastern Australia, interstate flows of grain strategically will become more important and will add to the volatility of Australia's grain exports.

In coming decades, export grain supply chains in Vic and NSW will be affected by the combination of limited growth in crop production and an increased frequency of interstate grain flows. Farmers and grain users are likely to react by increasing their investment in grain storage; especially whilst interest rates are low which makes the cost of carrying grain across seasons more affordable. If high-yielding varieties of easily stored feed grains like barley and lupins become available, these crops could feature more in farmers' crop portfolios. Farmers are likely to enlarge their focus on feed grain production and will target, more frequently, domestic market opportunities in eastern Australia, including local feed grain value-adding opportunities.

Farmers are likely to have increasing choices over where and when they sell grain, due to the low cost of storing grain (i.e. a low interest rate environment), and the emergence of more domestic market opportunities.

Conclusion

Relatively modest population growth in Australian grain production is expected towards 2030. By contrast, Australia's population is projected to increase by between 16 and 19 per cent by 2030. This means between 4.07 and 4.89 million additional people, mostly residing in eastern States. Despite this projected increase in population and the associated demand for feed and human consumption grains, little increase in the area sown to crops in Australia is envisaged.

The corollary is that, especially during periods of drought in the eastern States, domestic market opportunities in eastern Australia will drive grain flows and increasingly affect the viability of the ownership and operation of export grain supply chain infrastructure. Grain storage will increasingly form part of many businesses' risk management strategies. Establishing and maintaining low-cost interstate supply chains will be an increasing complementary strategic need.

References

Kingwell, R., Elliott, P., White, P. and Carter, C. (2016a) Ukraine: An emerging challenge for Australian wheat exports, Australian Export Grains Innovation Centre, April 2016. Available at: http://aegic.org.au/wp-content/uploads/2016/04/Ukraine-Supply-Chain-Full-Report.pdf

Kingwell, R., Carter, C., Elliott, P. and White, P. (2016b) Russia's wheat industry: Implications for Australia, Australian Export Grains Innovation Centre, September 2016. Available at: http://aegic.org.au/wp-content/uploads/2016/09/Russia-wheat-industry-Implications-for-Australia.pdf

Kingwell, R. and White, P. (2018) Argentina's grains industry: Implications for Australia. Available at: https://www.aegic.org.au/wp-content/uploads/2018/11/AEGIC-Argentina-Report_18_LR.pdf

Kingwell, R. (2019) Australia's grain outlook 2030. AEGIC Industry Report. Available at: https://www.aegic.org.au/wp-content/uploads/2019/11/AEGIC-Australias-Grain-Outlook-2030.pdf

Kingwell, R., Rice, A., Pratley, J., Mayfield, A. and van Rees, H. (2019) Farms and farmers – conservation agriculture amid a changing farm sector. In (Eds. J Pratley and J Kirkegaard) "Australian Agriculture in 2020: From Conservation to Automation" pp33-46 (Agronomy Australia and Charles Sturt University: Wagga Wagga).

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New chemistry – what's new, what's coming and how to keep them for longer

Greg Condon, Grassroots Agronomy & Australian Herbicide Resistance Initiative

Key words

herbicides, herbicide resistance, mix and rotate, mode of action, WeedSmart – The Big 6

Take home messages

- A range of new pre- and post-emergent herbicides will be available in the coming seasons which will broaden weed control options and use patterns
- Key releases include pre-emergent herbicides for cereals, pulses and canola from Groups E, G, O, Q as well as Group G options for knockdowns and fallows
- Mix and rotate herbicide modes of action to delay resistance and maximise weed control
- Herbicide resistance remains an ongoing threat. Non-chemical tools such as crop competition and harvest weed seed control are vital to complement and protect the longevity of new and existing chemistry.

Background

Herbicides remain an essential component of cost-effective weed control in Australian grain production systems. Growers spend over $1 billion per year on herbicides, with additional investment in crop monitoring, application technology and logistics to support their use. Therefore, it is critical for new modes of action and herbicide reformulations to be developed, so growers can manage shifts in weed populations, herbicide resistance and changing use patterns.

In recent years, manufacturers have been expanding the range of pre-emergent herbicides which complement no-till farming systems across a diverse range of soil types and seeding configurations. Older products such as trifluralin and triallate have provided early season weed control when applied in no-till seeding systems prior to sowing. Newer generation herbicides such as prosulfocarb + S-metolachlor (Boxer Gold®) or pyroxasulfone (Sakura®) have demonstrated greater flexibility with longer incorporation times prior to sowing and improved crop safety.

There are several new herbicides (Tables 1 and 2) that will provide further diversity in weed control options at various stages of the crop growth cycle. These include knockdown and fallow spikes, as well as pre-emergent broadleaf and grass weed herbicides. These will also reduce pressure on herbicide resistant populations when used in combination with non-chemical tools such as harvest weed seed control and increased crop competition.

New herbicides

Note: as several of the products listed below are at the time of writing not yet covered by registered product labels, the information supplied should not be relied on and a registered product label must be read and followed before products are used.

Table 1. New pre-emergent herbicides

Company	Trade name	Active & formulation	Group	Proposed crops	Rate/ha	Likely Cost $/ha	Proposed weeds	Proposed application
Adama	Ultro	900g/kg Carbetamide WG	E	most pulses (see label); winter fallow	tba	tba	barleygrass, brome, ryegrass, wild oats	IBS – knife points & press wheels only. PSPE – chickpeas
Comments: Registration planned for 2020, full launch 2021. 12 weeks grazing WHP. Likely: 7 days incorporation window. Lower rate for sandy soils and where lower weed densities are expected.								
BASF	Luximax®	750g/L Cinmethylin EC	Z	wheat (not durum)	500mLl/ha	$39	ryegrass suppression. wild oats, brome	IBS – knife point & press wheels only
Comments: Registered. Ensure seed is sown below the treated band, targeting a minimum of 3cm consistent sowing depth; 7 weeks grazing WHP. 3 days incorporation window. Predominantly root uptake, improved activity with mixing partners e.g. triallate, trifluralin. Target <50% stubble cover to reduce losses from binding.								
Bayer	Mateno® Complete (formally Bayer 167)	Aclinofen + others SC	new MOA	wheat, barley	tba	tba	tba - various grass and broadleaf weeds	IBS – knife point & press wheels or early post emergent
Comments: Registration expected for ~2022. New mode of action suited to stubble retained systems. Likely: Flexibility to apply IBS or early post emergent with activity on a range of grass and broadleaf weeds.								
Corteva Agriscience	Gallery®	750g/kg Isoxaben DF	O	wheat, barley, triticale, fallow, fencelines	IBS & PSPE 70-140g/ha early post em, 70-100g/ha	$17-30	wild radish	IBS, PSPE or early post emergent
Comments: Broadacre use patterns added in 2017. 6-week grazing WHP. Option to apply IBS, PSPE or early post emergent with a mix partner. Requires moist soil to remain active, needs 12-15mm to activate. Be wary of plantbacks, canola 22 months, pulses 9 months, cereals nil.								
FMC	Overwatch™	400g/L Bixolone SC	Q	wheat, barley, canola	tba	$43	tba - various grass and broadleaf weeds	IBS – knife points & press wheels only
Comments: Registration expected early 2020, full launch 2021. Aiming to register in a range of pulses by 2022. Likely: 12 weeks grazing WHP. Group Q bleacher, grass weeds emerge then bleach out. Can cause transient crop bleaching, barley is more sensitive, but recovery expected. Predominantly root uptake, improved activity with mixing partners e.g.: triallate, trifluralin. Low volatility suited to dry sowing. 3 days incorporation window.								

Syngenta	Callisto™	480g/L Mesotrione SC	H	wheat, barley	tba	$7.80-$15.60	see label when available - wide range of broadleaf weeds	IBS – knife points & press wheels only
Comments: Registration expected early 2020. Up to 10 weeks residual weed control on broadleaf weeds resistant to groups B,C,D,F & I. Likely: 10 weeks grazing WHP. IBS within 3 days, no-till systems only – do not use if soil has been cultivated. Can mix with knockdown and pre-emergent grass herbicide. A light activated herbicide, can observe a bleaching effect on crop and weed leaves.								
Syngenta	Reflex®	240g/L Fomesafen SL	G	Range of pulses	tba	tba	see label when available - wide range of broadleaf weeds	IBS – knife points & press wheels only
Comments: Registration planned for 2021. Pre-emergent option in pulses controlling resistant broadleaf weeds. Extended residual period compared to Group C chemistry. Root absorbed, no leaf uptake. Likely: IBS and PSPE. IBS only for lentils. IBS within 10 days. PSPE rainfall within 17 days.								

Table 2. New group G knockdown spikes and residual herbicides

Company	Trade name	Active & formulation	Group	Proposed crops	Rate	Likely cost $/ha	Proposed weeds	Proposed application
BASF	Voraxor®	250g/L Saflufenacil + 125g/L Trifludimoxazin	G	wheat, durum, barley	tba	$12.50-30	see label when available- wide range of grass and broadleaf weeds	IBS – knife points & press wheels only
Comments: Registration expected for 2020, full launch 2021. Likely: 5 weeks grazing WHP. Knockdown and residual control of broadleaf weeds plus suppression of ryegrass. Broadleaf residual control for 8-12 weeks (at higher application rates). Partner with glyphosate as a knockdown spike or mix with paraquat for double knock applications. Do not mix with pre-emergent herbicides such as Boxer Gold®, Luximax®, trifluralin or Sakura® as increased crop damage may occur.								
Nufarm	Terrador	700g/kg Tiafenacil WG	G	knockdown spike	tba	tba	see label when available - wide range of grass and broadleaf weeds	
Comments: Registration and commercial launch planned for early 2021. Likely: Partner with glyphosate as a knockdown spike or mix with paraquat for double knock applications. Expected suppression of grasses as a knockdown partner with glyphosate or paraquat. 1 hour plant back for cereals and pulses, anticipate 7 – 14 days for canola depending on use rate.								

Always consult the label for further information regarding any of these herbicides.

IBS – incorporated by sowing.

PSPE – post sowing pre-emergent

Test, mix and rotate

With new herbicides coming to the market, testing your resistance (or susceptibility) status is a logical first step when planning a weed control program. Growers and advisers can utilise the data from resistance testing services to develop an understanding of what works and what doesn't. Further value is gained by testing herbicide mixtures as well as single modes of action to aid planning product combinations.

Resistance testing services are available nationally through three providers: Peter Boutsalis, Plant Science Consulting, Adelaide; John Broster, Charles Sturt University, Wagga Wagga; Roberto Busi, AHRI, University of Western Australia, Perth.

An expanded range of herbicides creates opportunities for the rotation of herbicide modes of action and the ability to mix with existing chemistry. Research by Dr. Pat Tranel from the University of Illinois, USA found that resistance can be mitigated by mixing herbicides at full rates. Pat is quoted saying "Rotating buys you time, mixing buys you shots". Peter Newman from AHRI expanded on the concept to recommend that we mix herbicides and rotate modes of action so that we can "buy time and shots."

Modelling by Roberto Busi from AHRI and Michael Renton from UWA has also shown the benefits of mixing and rotating herbicides for ryegrass. The modelling highlighted that rotating groups alone doesn't work. Herbicide resistance evolution needs to be managed through the mixing and rotation of herbicides along with non-chemical tools to keep seedbanks low.

The mix and rotate strategy will not only provide improved weed control but more importantly aids in resistance management where unpredictable patterns of cross-resistance are evolving. Even the best pre-emergent herbicides can be broken by resistance if not managed wisely.

Populations of ryegrass from the Eyre Peninsula in South Australia have recently been confirmed as resistant to all the pre-emergent herbicides – triallate (Avadex®), prosulfocarb (Arcade®), trifluralin, propyzamide and pyroxasulfone (Sakura®). These findings by the University of Adelaide have huge implications for an industry now heavily dependent on pre-emergent herbicides in no-till systems, showing they can quickly break down in the face of metabolic cross-resistance.

Repeated applications of the same herbicides in simple canola-wheat rotations have allowed ryegrass to develop metabolic cross resistance. This is in the absence of alternative tactics such as croptopping, hay, harvest weed seed control or diverse rotations which create opportunities to run down the weed seedbank.

Protecting the chemistry – WeedSmart - The Big 6

The Australian grains industry leads the world in the development and communication of integrated weed management tactics. WeedSmart provides a portal where growers and advisers can source a broad range of information on managing weeds. It brings together information from research groups, leading growers, agronomists and industry to promote best practice agronomy and weed management.

As new chemistry becomes available it is crucial for all involved to protect the longevity of any new products and minimise the risk of resistance. The WeedSmart Big 6 combines weed research data with grower experiences to create a set of practical guidelines focused on minimising the weed seedbank without compromising profit.

The WeedSmart Big 6:

1. Rotate crops and pastures
2. Double knock – to preserve glyphosate
3. Mix and rotate herbicides
4. Stop weed seed set
5. Increase crop competition
6. Adopt harvest weed seed control

Tactics such as harvest weed seed control, crop competition, hay and diverse rotations complement herbicide options including mix and rotate, double knock, pre-emergent herbicides and late season crop-topping. Site specific applications using optical spray technology enhance double knocks in fallow, reducing herbicide inputs by increasing options to introduce diverse chemistry.

Grower success in reducing seedbanks but staying profitable has been achieved through stacking Big 6 tactics over an extended period of time. For example, a diverse rotation with pulses, competitive barley and hybrid canola combined with robust pre-ems, croptopping and chaff decks is an achievable system where five of the Big 6 tactics are stacked together.

The Big 6 is based around practical weed control tactics, used in conjunction with best practice agronomy to reduce the risk of resistance and drive weed seedbank numbers to zero.

Conclusion

New chemistry creates opportunities for targeting resistant weeds or managing resistance through alternative use patterns. Crop protection companies invest significant capital into the research and development of new or reformulated herbicides. In order to protect this investment, the industry needs to continue working together to ensure farming practices include both chemical and non-chemical weed control options to keep seedbanks low and minimise the risk of resistance.

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Useful resources

https://csu.edu.au/plantinteractionsgroup/herbicide-resistance
http://plantscienceconsulting.com.au

References

Brunton D, Boutsalis P, Gill GS, Preston C (2018). Resistance to multiple PRE herbicides in a field-evolved rigid ryegrass *(Lolium rigidum*) population. Weed Sci. 66:581-585

Congreve, M and Cameron, J (eds) (2019). Soil behaviour of pre-emergent herbicides in Australian farming systems – a national reference manual for advisers. 2nd edition. GRDC publication.

Congreve, M (2019). Mixing knockdown partners with Group G herbicides. GRDC publication.

http://ahri.uwa.edu.au/alphabet-cross-resistance-in-south-australia

http://ahri.uwa.edu.au/mixing-herbicides-wins-again

http://ahri.uwa.edu.au/susceptibility-testing

http://weedsmart.org.au/how-can-i-implement-the-mix-and_rotate-strategy-to-combat-herbicide-resistance/

http://weedsmart.org.au/the-big-6

Preston C (2019). Managing weed seeds is a focus of herbicide resistance strategies. Groundcover. GRDC publication.

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Is our ryegrass really getting harder to kill through our over reliance on glyphosate?

Maurie Street & Ben O'Brien, GOA

Key words

annual ryegrass, glyphosate, herbicide resistance

GRDC code

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Take home messages

Glyphosate resistance is real and affirmative action needs to be taken now and into the future - BUT:

- The assumption of "herbicide resistant" may be applied too hastily in some cases to herbicide failures
- Many other influences can result in poor herbicide performance. Growers and agronomists need to critically assess any failures to establish true causes
- Populations of weeds suspected to be resistant should be tested to confirm resistance otherwise useful options for control may be overlooked.

Background

Annual ryegrass (ARG) is considered one of the major weeds in the cropping systems of central west NSW and it is commonly resistant to one or more herbicides. It is present on nearly all farms and is never far from mind in any weed control program.

Populations are very commonly resistant to Group A-fops and Group B-sulfonyl urea herbicides (GOA Herbicide resistance surveys web results) with other effective in-crop selective control options becoming limited. However, there are an increasing number of confirmed cases of resistance to glyphosate (Group M). In 2013 and 2014 Grain Orana Alliance (GOA) ran two herbicide resistance surveys in central western NSW which tested 130 non-random or 'submitted' samples of ARG. Results of these surveys revealed 26% of the samples tested were resistant to glyphosate. A recent survey undertaken by CSU and funded by the GRDC, testing randomly selected ARG samples from the northern region showed 10% to be resistant to Group M herbicides, a level much higher than many other regions. This paper looks at how our farming practices have evolved to deal with glyphosate resistant ryegrass.

Personal experience of one of the authors, whose agronomy career started in the early 90's, recalls that 'in the good old days' ARG was certainly ever present but glyphosate was very effective with pre sowing knockdown use rates of 500 mL/ha of 450 gai/L product being commonplace, particularly when followed by a full disturbance sowing. Compare this to today, where field rates are seldom below 1500 mL/ha of a 450 gai/L and there is a push to even higher rates still to control the weed spectrum. Furthermore, there is an increase in the use of double knocking, more use of pre-emergent residual herbicides, re-introduction of cultivation, the use of crop topping and the adoption of harvest weed seed management techniques such as chaff lining or windrow burning all in the attempt to manage herbicide resistant weeds – including ARG. Arguably the control of ARG has become more complex and it is more difficult to kill in a farming system that relies heavily on herbicides, particularly glyphosate.

Given the resistance survey results and the increasing efforts in our weed control systems to control ARG, it is not unreasonable for growers or advisers to automatically assume resistance in populations that are not well controlled by glyphosate. However this assumption of resistance is not always confirmed by testing of the population.

Where growers are wanting to control or slow the development of resistance in ARG, alternate knockdown options are very limited. As a result, GOA was asked to investigate alternate herbicides or options to improve the herbicide control of problematic ARG populations ahead of seeding winter crops and established a number of trials over the past three years.

Some of the results are not unexpected but we did find some encouraging and surprising outcomes. Full details can be found on the GOA website. http://www.grainorana.com.au

What did we do?

Growers and advisers were asked to identify paddocks with problematic populations of ARG. In all cases the sites put forward were strongly suspected as resistant to glyphosate with previous cases of poor control.

GOA then employed two different trial protocols at each site:

1. Investigate options to improve glyphosate control of seedling ARG through product rate, formulation and adjuvant packages
2. Investigating various alternate herbicide options to glyphosate to control seedling ARG.

What did we find?

Resistant ryegrass populations

From 2017 to 2019 GOA established trials on seven separate populations of ARG.

Sites were selected prior to sowing, following rainfall, where there were good populations of emerged ARG. At the time most sites selected were at least strongly suspected as being resistant to glyphosate due to poor and unreliable control in previous seasons, although many had never had this confirmed by testing.

Clearly from the plant populations present, often greater than 200 plants/m^2, ARG has been problematic to control in the past allowing the seed bank to grow.

Once the trial site was selected, live ARG samples were collected and sent to Plant Science Consulting for herbicide resistance testing using their Quick Test Service (details of the methodology of the Quick Test can be found at www.plantscienceconsulting.com.au.

The results were surprising. Of the seven populations strongly suspected and being managed as resistant to glyphosate, only two were confirmed as resistant by testing. One had only low level of survival of 10% and survivors demonstrated moderate resistance (RR), the other sample had slightly higher resistance of 20% but only a weak resistance (R) rating. Furthermore, this level of resistance was only evident at rates much lower (500 mL/ha & 750 mL/ha Roundup® CT) than field rates typically applied in present day (>1500 mL/ha) with none detected at higher rates.

Looking at this from the other angle - in these two cases 80%-90% of the plants tested were controlled by glyphosate (at the low rates) and the survivors stunted. If 90% kill rate is deemed acceptable commercial control, even low rates should be achieving close to this on these two populations. If growers are applying higher rates of glyphosate, which likely would be the case, the level of resistance cannot be wholly blamed for failure to control these populations. So, what is responsible for the failure in control?

In the remaining five, confirmed susceptible populations, the poor/unreliable control cannot be explained by resistance, so what caused these failures?

Improving glyphosate performance through product choice, rate or the addition of surfactants or adjuvants

The mechanism of resistance to Group M in ARG is often, but not always, rate responsive. As detailed above, two populations did show resistance at lower label rates of glyphosate, but all those populations could theoretically be controlled at a reasonable level if the rate was increased.

This trait is a weakness in the resistance mechanism that can be exploited by growers and advisers to both manage resistant populations and/or reduce the rate of development of resistance. How effective this may be is related to the type and the level of resistance present in the population at the time of application.

GOA trials aimed to demonstrate a typical dose response to confirm that higher rates are justified for the control of resistant ARG.

The impact of rate on control of ARG is detailed in Table 1. In all but one case there was a positive response to increasing the rate of Roundup® CT and acceptable control was able to be achieved.

Table 1. Percentage control of untreated population of annual ryegrass in response to rate of Roundup® 450 CT.

	Year	2017						2018				2019			
	Location	Narromine		Parkes		Alectown		Narromine		Alectown		Tichborne		Forbes	
	Weed size	3-6 leaf		3-6 leaf		3-6 leaf		3-5 leaf		3 leaf- 2 tillers		2-6 leaf		6 leaf- early tillering	
Roundup CT ®L/ha + Wetter TX®	UTC	0	E	0%	J	0%	H	0%	A	0%	F	0%	B	0%	A
	0.50							99%	BC	54%	CDE	54%	C	56%	ABCDE
	0.75	31%	D	88%	EFGH	30%	EGH	100%	C	63%	BCD	60%	C	89%	EFGH
	1.00							100%	C	71%	BC	55%	C	98%	IJ
	1.25							100%	C	80%	AB	67%	C	100%	J
	1.50	99%	A	96%	ABCDE	95%	A	100%	C	93%	A	64%	C	100%	J
Resistance testing		Yes		ND		ND		ND		Yes		ND		ND	

Results followed by the same letter only at the same location denotes no significant difference, p= 0.05
Resistance- yes- glyphosate resistance was detected by testing, ND- Glyphosate resistance not detected
UTC – untreated control

The Narromine 2017 and Alectown 2018 sites are confirmed resistant. Alectown was the most difficult of the two to control but plants were largest at this site and moisture deficits were observed at the time of spraying. An acceptable level of control was still achieved with the high rates in both cases.

'Tichborne 2019', was not adequately controlled but was confirmed as susceptible. Both Tichborne and the Forbes 2019 sites were noted as very dry, somewhat stressed with warm spraying conditions, yet the one with the largest weed size (Forbes) was controlled readily, the other not.

This situation is an example to illustrate the difficulty growers and advisers face in diagnosing resistance in the field. Both sites were sprayed within one day of the other, the same water source was used as was the spray set up. We were confident in that our spray application was satisfactory so the failure in ARG control observed was thought as confirmation of the assumed resistance. Testing was carried out as a matter of course and it was not until several months later, when the tests results were returned, that the misdiagnosis was exposed.

GOA also looked at two other key aspects; the impact of surfactants or spray adjuvants and the choice of product looking to address the question- "Should growers add additional surfactants or buy a different formulation of glyphosate?"

Commercially available formulations of glyphosate often contain different levels and different types of surfactant to aid in the deposition and absorption of glyphosate to improve control. However additional surfactants are sometimes suggested in certain situations to further improve control - such as controlling ARG in some situations.

The need for additional surfactants is very complex with a range of different glyphosate salts, concentrations and surfactant packages used in current formulations. Salt types respond differently to surfactant packages, in a similar way that some weeds respond differently to particular surfactants (see https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2018/08/factors-to-consider-with-the-use-of-different-glyphosate-formulations). Different formulations have more or less surfactant in their formulations- altering the need for any additional surfactants. Further adding to the complexity of the decision is that the surfactant type and concentration in the glyphosate formulation is generally not made available via the product label, so it is often unclear if surfactant in the formulation is optimised or not. Further, there is often a misunderstanding of what is the optimal type of surfactant that will be most useful for glyphosate, perhaps this is not helped by the many inconsistencies or ambiguity in labels as to the need for (or the benefit of) additional surfactant.

A range of common surfactants were tested to observe the potential impact on ARG control as well as testing some other formulations/brands of glyphosate (2017 only). This treatment list is rather simplistic, but it was thought that it could help growers' decisions in their choices to control ARG.

There was no consistent difference in performance of Roundup® CT®, Roundup ULTRA® MAX (a premium, fully loaded product) or a low priced- generic brand if robust rates were used. However, at the lower rates tested, Roundup ULTRA® MAX often performed better than the other two products tested.

The same could generally said regarding surfactants. In general, at robust rates of glyphosate in the large majority of cases tested, there was no advantage to the addition of any of the following: BS1000®, LI700®, Liase®, Wetter TX® or Activator®. At lower glyphosate rates, the addition of these sometimes did improve control, but often not to the levels achieved with higher rates of glyphosate and the response was inconsistent. Put simply, if there is a choice to increase rate or add additional surfactants or additives, in the circumstances tested, the most consistent result was to increase the rate.

What is not always clear is whether the benefits of increasing the glyphosate 'product' rate per ha, is due to the increase in active ingredient as opposed to the increase in inbuilt surfactant loading.

GOA was able to secure a non-commercial formulation of IPA glyphosate at 620g/L (Gly 62% UPA), that had no surfactant added. We trialled adding a surfactant used in some commercial formulations of glyphosate at various rates to reflect a range that may be found in commercial products. It is often suggested that various commercial brands of glyphosate vary largely by the type and rate of co-formulated surfactant used. It has been commonly accepted that surfactant inclusion in most commercial 450gai/L products is 12%. However, some poor quality brands may contain much less than that, with inclusion rates down as low as 4% or nil in some extreme cases.

At Parkes in 2018 control with GLY 62% IPA at a sub optimal rate, improved significantly with increasing rates of surfactant added, confirming that increasing surfactant rates do play a part in improving control. It should be noted that the rate of glyphosate used in this trial was very low and the carrier volume relatively high at 100L/ha. However as discussed above, where commercial glyphosate formulations already have sound rates and types of surfactant included, such as Roundup® CT, additional surfactant may only be warranted where surfactant is diluted at low herbicide rates and/or high-water rates as is demonstrated by this trial.

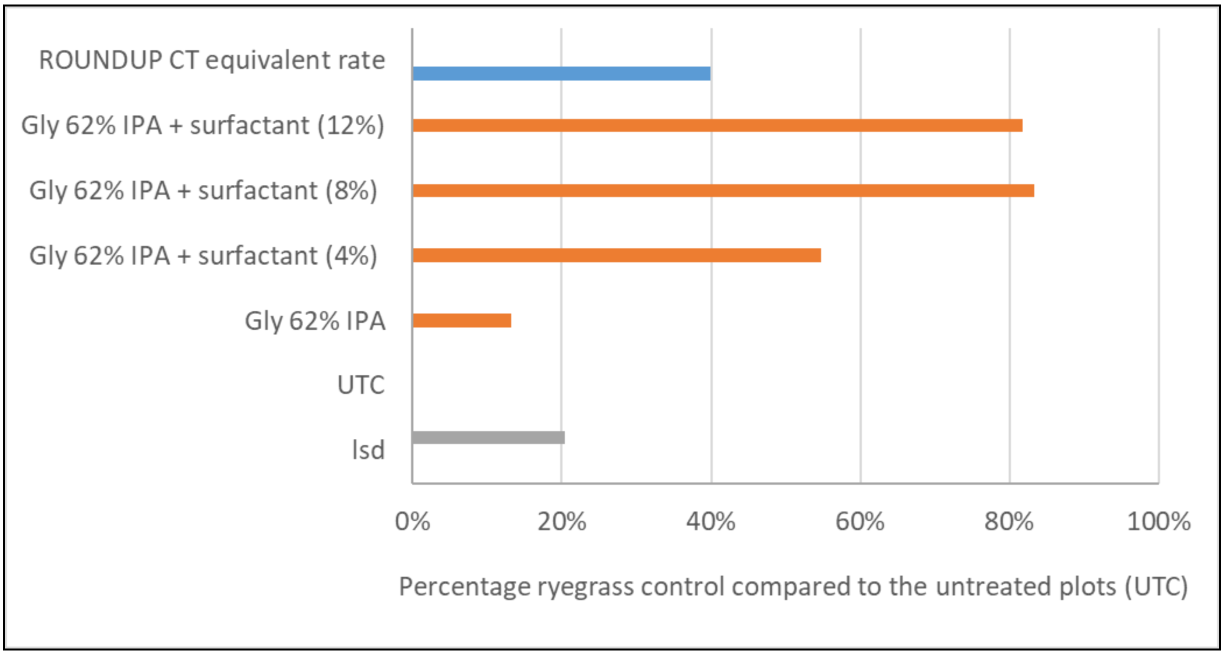

Figure 1. Impact on ARG control by increasing rates of additional surfactant mixed with a very low dose rate of IPA glyphosate with no surfactant at the relatively high spray carrier volume of 100L/ha (Parkes, 2018).Alternate options to control ARG

Another option to control a resistant population is to use alternate effective modes of actions. Paraquat or products containing paraquat are often the most logical as they have labelled use patterns, that means growers can use them as a substitute in many knockdown situations or alternatively it can be used as a double knock spray following use of glyphosate or other products.

Paraquat was both tested as a single pass options as well as a double knock treatment with results similar to Borger & Hashem (2007) and Newman & Adam (2004). Where paraquat was used as a double knock, control was improved substantially. When used as a single pass option, results were more variable but useful control was still often achieved.

Alternate options investigated included some Group A, K + J, H or G herbicides as either a standalone or a spike to aid in the knockdown of ARG.

Whilst all of the evaluated products are currently unregistered for use in this situation, the results confirmed they were generally not effective in controlling ARG.

The Group A herbicides, in particular the Fops- were all but ineffective, but this is not surprising given the resistance status of most ARG populations. The DIMs in many cases did not achieve commercially acceptable control when applied alone but when mixed with Roundup® CT, control was better but generally no better than glyphosate applied alone.

The Group K+J, H and G herbicides were applied with Roundup® CT and showed little advantage over that of Roundup® CT alone. In all cases better control could be achieved with higher rates of glyphosate.

In Summary

The presumption of glyphosate resistance in five of seven sites, has shown to be incorrect. It is not doubted that the populations have proved problematic with previous applications, but it could be said in most, if not all cases the poor control was not the result of resistance alone.

Of greater concern, is that if failure was not due to resistance, why was control so poor? There are many possible reasons such as poor spray water quality, incorrect spray timing, inappropriate sprayer set up delivering less than optimal spray droplet size and/or water rates, products with sub-optimal surfactant loadings, plant or environmental stresses. All these issues can result in poor control, and in the event of herbicide failures, all aspects of the application should be reviewed or investigated - including Stress; Timing; Application and Rate (STAR).

Furthermore, the results of these trials highlight the value of herbicide resistance tests in the event of a failure. Tests would have revealed that in all seven paddocks, glyphosate was still effective albeit at a higher rate for some.

A clear outcome from these trials is for growers to move to higher rates within label guidelines if not already doing so. Higher rates are a sound way to maximise control whether resistance is present or not and may be more effective than any investment in additional surfactants. It must be noted that the decision to add adjuvants to improve water quality, for example using Liase for hard water, should also be addressed.

Indeed, this view is pointed out by Boutsalis et al. (2015), increasing glyphosate rates may also contribute to more effective control by "… counteracting poor application, improving control of older plants, stressed plants or overcoming reduced efficacy caused by using poor quality water or treating plants covered by dust. Higher label rates can also improve glyphosate activity on plants exposed to higher temperatures that can arise in early autumn or late spring".

In reply to the title question- is ryegrass getting harder to kill? I think we could say that controlling ryegrass has become more complex. In many cases glyphosate resistance is most definitely present, and this is harder to deal with. But it has been demonstrated that resistance is not the only thing making it harder to control.

The most important take home is to review spray failures. The first and arguably easiest 'failure parameter' to eliminate is resistance, so get it tested. That way you know what you are dealing with and what will work and what won't work in subsequent management sprays. Simply assuming resistance may see useful options overlooked and a failure to identify and address the real cause of any spray failures.

References

Boutsalis P, Gill G and Preston P (2015). Optimising the impact of glyphosate. GRDC Grains Research Update paper. Retrieved from: https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/02/optimising-the-impact-of-glyphosate

Borger, C., & Hashem, A. (2007). Evaluating the double knockdown technique: sequence, application interval, and annual ryegrass growth stage. Crop & Pasture Science, 58(3), 265-271. Retrieved from https://academic.microsoft.com/paper/2022301494

GOA herbicide resistance surveys web results. Retrieved from: http://www.grainorana.com.au/documents?download=36

McNamara E (2017) Ryegrass resistance continues to spread. GRDC media release. Retrieved from: https://grdc.com.au/news-and-media/news-and-media-releases/north/2017/09/ryegrass-resistance-continues-to-spread

Newman, P and Adam G (2004). Double knock down, one day between knocks. Retrieved from: https://ahri.uwa.edu.au/wp-content/uploads/2015/04/PNewman-doubleknock-cropupdates-04-.pdf

www.plantscienceconsulting.com.au

Somervaille A (2018). Factors to consider with the use of different glyphosate formulations and getting it right with the use of adjuvants. GRDC Grains Research Update paper. Retrieved from: https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2018/08/factors-to-consider-with-the-use-of-different-glyphosate-formulations

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NVT Online: robust, reliable variety selection decisions

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Notes

Summer cover crops in short fallow - do they have a place in central NSW?

Colin McMaster, Allan Stevenson and Stuart Strahorn, NSW Department of Primary Industries, Orange

Key words

cover crop, stubble cover, ground cover, short fallow

GRDC code

DAQ00211

Take home messages

- Summer cover crops reduced the winter cash crop (wheat) grain yield by up to 1.5 t/ha at Canowindra and 0.6 t/ha at Parkes
- Grain yield losses were minimised by spraying out the cover crop early
- The grazing value ($/ha) generated from the cover crop more than compensated for the grain yield reduction based on current commodity prices
- Pros of summer cover crops include increased ground cover, reduced soil erosion from wind and water, cooler and more consistent soil temperatures, improved autumn sowing conditions, valuable summer forage for mixed farming operations, quicker soil water recharge compared with bare ground, reduced herbicide applications over the summer fallow, and improved total soil carbon % and assumed microbial activity
- Cons of summer cover crops include reduced mineral nitrogen and reduced grain yield for the following winter cash crop, increased risk of soil water deficit in low rainfall years (or greater reliance on in-crop rainfall), additional seed costs, patchy establishment of summer cover crop due to rapidly drying soils, high herbicide rate required to terminate cover crop, and increased disease risk (stubble and soil) due to green bridge for the following winter cash crop
- Risks associated with cover crops are reduced by: longer fallow period post cover crop for soil moisture recharge and mineralisation of cover residue; incorporating livestock within the system to convert surplus biomass to $/ha; seasons with high rainfall; additional nitrogen fertiliser application for winter cash crop
- The optimum ‘crop type selection’ and ‘spray out timing’ will vary depending on individual paddock and enterprise goals.

Background

Dust storms have been a common sight in central NSW in the summer of 2019/2020 due to the combination of drought and low ground cover. Ground cover levels have been on a decline since 2017 with residual stubble decomposing over this time, and limited opportunity to grow fresh biomass over the past 2-3 years. Factors further reducing ground cover levels include growing low biomass pulse crops (e.g. chickpeas), incorporation of lime, grazing stubbles and baling of failed winter crops. Both the magnitude and duration of the current dry period has been unparalleled and is highlighting the value of ground cover.

The benefits of cover crops to protect the soil from wind or water erosion in low stubble scenarios is well understood, however the use of cover crops as a technique to improve water infiltration and storage to improve grain yield for the following winter cash crop is less clear. Recent GRDC funded research (McMaster 2015) has demonstrated that 50% of yield potential can be attributed to summer rainfall and summer fallow management as a result of increased stored water and nitrogen (N). Water and nitrogen increase grain yield through grain number (more tillers and more grains per head) and grain size, with a return on investment of controlling summer weeds between $2.20 and $7.20 ha for every dollar invested.

The primary purpose of these experiments was to evaluate if there is a net water gain to the subsequent winter cash crop (wheat) following a summer cover crop, and the associated result on grain yield. The secondary purpose of this project was to evaluate the impact of various spray-out timings (early, mid and late) and crop-types (including single species, mixed species and summer weeds) on the farming system, including grazing value of cover ($), crop nutrition (mineral N and total carbon %), disease pressure (stubble and soil), and soil temperature.

Method

Two sites with zero ground cover were selected in central NSW at Canowindra (high rainfall zone – central east (CE) slopes) and Parkes (medium rainfall zone – central west (CW) plains). Each site consisted of a short and long fallow treatment and the experiment design was a randomised block with 4 replications. Individual plot size was 10m X 10m across all experiments. The following report provides results from the short fallow experiments only, and includes treatment combinations of four cover crops, three spray-out timings and one control (bare ground, weed-free). The summer cover crops were sown using a knife point press wheel plot seeder at 30cm row spacing and the subsequent winter cash crop was sown with a single disc plot seeder (30cm row spacing) due to trash flow requirements. Fertiliser was applied with the seed, at a rate of 50 kg/ha of mono ammonium phosphate (MAP) with the cover crop and 50 kg/ha MAP with the winter crop. The summer cover crops were sown on 26 November (2018) at Canowindra, and 9 December (2018) at Parkes. The subsequent winter crop (Wheat – cv Mustang⦇) was sown on 18 May at Canowindra, and 25 May at Parkes.

Short fallow trial (6-month fallow – November 2018 to April 2019)

Treatment details:

- Treatment 1: Cover crop types = cow peas, forage sorghum, mixed species and summer weeds
- Treatment 2: Spray out timings = 50, 80 and 110 days after sowing the cover crop (DAS)
- Treatment 3: Control = bare ground kept weed-free.

The mixed species included cow peas, lab/lab, forage sorghum, millet, tillage radish and sunflower.

Results and discussion

Seasonal conditions and crop establishment

Table 1. Monthly rainfall and long-term average (LTA) rainfall for Canowindra and Parkes, 2019.

Month	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Canowindra													
Rainfall (mm)	39	34	45	53	1	33	34	13	24	21	20	17	7
LTA (mm)	53	57	50	49	40	44	48	50	48	42	51	49	53
Parkes													
Rainfall (mm)	21	28	23	*32*	0	29	25	13	10	18	27	11	7
LTA (mm)	54	58	50	46	43	44	50	51	50	46	56	51	54

Table 2. Seed rate, seed cost and field establishment of summer cover crops at Canowindra and Parkes, 2019.

Treatment		Seed rate	Seed size	Seed cost	Seed cost	Canowindra		Parkes	
		(kg/ha)	Seeds/kg	(per kg)	(per ha)	(Plants m^2)[b]	Est (%)	(Plants m^2)[b]	Est (%)
Forage sorghum		9	32100	$5.20	$46.80	26.8	93%	22.8	79%
Cow pea		16	9500	$3.90	$62.40	12.5	82%	12.6	83%
Mixed species[a]	forage sorghum	2	32100	$5.20	$10.40	4.9	76%	5.2	81%
	millet	5	124000	$2.50	$12.50	19.5	31%	11.3	18%
	cow pea	4	9500	$3.90	$15.60	2.6	68%	3.5	92%
	lab lab	4	4300	$4.00	$16.00	1.5	87%	1.5	87%
	sunflower	1	21052	$20.00	$20.00	1.3	62%	0.6	29%
	tillage radish	1	44642	$9.50	$9.50	5	112%	3.7	83%

[a] = Total seed cost for the mixed species treatment was $84/ha
[b] = Actual plants established per m^2

Cover crop biomass

Canowindra site

Biomass production ranged from 0.07 to 10.8 t/ha (Table 3) and was influenced by crop type (P<0.001), spray-out timing (P<0.001) and the interaction between both (P<0.001). Highest biomass produced across the site was 10.8 t/ha of forage sorghum (sprayed out late), compared with the lowest biomass produced by summer weeds (sprayed out early) with 0.07 t/ha.

On average across crop-types, forage sorghum (6.5 t/ha) and mixed species (3.4 t/ha) produced much higher biomass than the cow pea (1.3 t/ha) and summer weed (1 t/ha) treatments. Average biomass production further increased as spray-out timing was delayed from early, mid to late with a respective increase of 1.33 t/ha, 2.99 t/ha and 4.85 t/ha. Nitrogen fertility at this site was high (refer to crop nutrients section) and might explain why biomass production was relatively high at this site. Refer to Table 3 for individual biomass treatment results and Table 5 for feed test results.

Parkes site

Biomass production varied from 0.10 to 2.09 t/ha (Table 4) and was influenced by crop type (P<0.001), spray out timing (P=0.005) and the interaction between both (P=0.05). Biomass results were much less than Canowindra, yet the treatments still ranked similarly with forage sorghum (sprayed out late) producing the highest biomass of 2.09 t/ha, and summer weeds (sprayed out early) the lowest at 0.10 t/ha.

On average, forage sorghum (1.48 t/ha) produced more biomass than mixed species (0.94 t/ha), cow pea (0.36 t/ha) and summer weed (0.09 t/ha) treatments. Biomass increased as spray-out timing was delayed from early (0.33 t/ha) to mid (0.95 t/ha), but there was no further increase from mid to late (0.87 t/ha) spray-out timing. Refer to Table 4 for individual biomass treatment results and Table 6 for feed test results.

Interestingly, the millet seed was much less robust than forage sorghum due to lower plant establishment (Table 2) and crop growth appeared to be visually more affected by the higher temperatures than the forage sorghum. For example, the millet foliage turned limp and floppy whilst the forage sorghum foliage became spikier and more erect (similar to a drought stressed wheat crop). Consequently, millet contributed very little biomass in the mixed species treatment.

Soil temperature at 10cm depth

Canowindra site (11 April at 3pm)

The average soil temperature was 22.2°C and ranged from 18.9°C to 24.3°C. Soil temperature reduced as cover crop biomass increased and was affected by crop type (P<0.001), spray-out timing (P<0.001) and their interaction (P<0.015).

On average, the higher biomass crop types had cooler soil temperatures, with forage sorghum and mixed species being a respective 4.4°C and 3.8°C cooler than the bare ground, cow pea and summer weed treatments. There was no significant difference between the lower biomass crop types of cow peas, summer weeds and bare ground treatments. As spray out timing was delayed, the early and mid-timings were 1.3°C and 2.9°C cooler than the bare ground, respectively. Interestingly, there was no additional cooling effect from the mid and late spray-out timing. Refer to Table 3 for individual treatment results.

Additionally, higher biomass plots were cooler and provided a more consistent soil temperature around the mean when compared to bare ground (data not shown). During the period of 8 March to 20 May, when the bare ground treatment had a range (difference between the daily minimum and maximum temperature) of 10°C or 5°C, the forage sorghum (late spray-out) had a respective range of 6.4°C or 2.5°C.

Cooler soil temperatures would be an indication that evaporation rates were initially reduced under the higher biomass plots. Aside from soil water, higher biomass residues could enable earlier sowing opportunities for winter cereal grazing crops as cooler soil temperatures improve coleoptile length and establishment. Soil temperatures greater than 25°C can reduce crop establishment in winter cereals (Edwards 2006). Conversely, the more consistent soil temperatures of the higher biomass plots could potentially enable summer grain crops such as sorghum to be sown into cooler temperatures than previously practised (Serafin *pers. comm*).

Parkes site (measured 12 April at 3pm)

Parkes was 4.7°C hotter than Canowindra, with an average soil temperature of 26.9°C, ranging from 25.8°C to 27.6°C. Soil temperature was significantly affected by crop type (P=0.013), and the interaction between crop type and spray-out timing (P=0.052). Spray out timing was not significant (P=0.697). Parkes is a hotter region which explains the higher soil temperatures; however, the smaller range of soil temperatures is more of an indication of less biomass produced at this site.

Forage sorghum was 0.8°C cooler than the bare ground treatment. There were no significant differences between the lower biomass plots of bare ground, mixed species, cow peas or summer weed treatments. Refer to Table 4 for individual effects.

Crop nutrients (mineral nitrogen and total carbon %)

Canowindra site

Average mineral nitrogen (N) was measured before sowing the winter crop on 1 April. Sampling depth was 1.2 metres and the site average was 272 kg N/ha, and ranged from 195 kg N/ha to 343 kg N/ha. Mineral N was influenced by crop type (P=0.018) and spray out timing (P=0.053), but the interaction between both was not significant (P=0.676). Site mineral N was highly variable within treatments, and possibly a legacy effect from the previous canola crop (2018) that was grazed out due to drought.

Highest mineral N was achieved in the bare ground treatment (320.6 kg N/ha), and on average reduced by 79 kg N/ha for the higher biomass crop-types such as forage sorghum and mixed species, and by 46 kg N/ha and 10kgN/ha for the lower biomass crop-types such as cow peas and summer weeds, respectively. Cow peas had little positive effect on soil nitrogen levels and this may be due to: poor nodulation caused from the high temperatures; lazy nodulation due to high nitrogen levels.

Average total carbon percentage was 2% in the 0-10cm soil depth and ranged from 1.75% to 2.25%. Compared with the bare ground treatment (1.76%), total carbon increased by 0.36%, 0.33%, 0.22% and 0.11% in the forage sorghum, mixed species, summer weed and cow pea treatment, respectively. The average total carbon percentage in the 10–30cm was 0.64%, and there were no treatment effects.

Parkes site

Average mineral N was 103.2 kg N/ha and ranged from 61.3 kg N/ha to 152.8 kg N/ha. Mineral N was reduced as the cover crop biomass increased, and was affected by crop type (P=0.019), but not by spray-out timing (P=0.093) or interaction of both (P=0.414)

The bare fallow treatment had the highest mineral N with 152.8 kg N/ha, and then reduced on average by 69.5 kg N/ha, 61.1 kg N/ha, 50 kg N/ha and 34.6 kg N/ha for forage sorghum, mixed species, cow pea and summer weed treatments respectively. Refer to Table 4 for individual effects.

The average total carbon percentage was 1.01% in the 0–10cm depth, and 0.48% in the 10–30cm depth. There was not enough biomass produced to alter total carbon at either depth.

Soil water accumulation

Canowindra site

As expected, over the summer period the various cover crops extracted moisture from the soil profile to grow biomass. After cover crop termination there was approximately a 50mm water deficit between the driest and wettest plot (Figure 1). Soil water levels were affected by crop-type (Figure 2a) and spray-out timing (Figure 2b), but no interaction between the two .

The higher biomass crop-types such as forage sorghum and mixed species extracted more moisture than lower biomass crops such as cow pea and summer weeds (Figure 2a). Additionally, spray-out timing also impacted soil water with the mid and late spray-out timing being approximately 30mm dryer than the early spray-out (Figure 2b). Despite the soil water deficit at cover crop termination, the higher biomass plots recharged quicker than the bare ground treatment resulting in no statistical difference in soil moisture from the 16 April to 12 November. The rate of recharge was a surprising result and warrants further investigation to determine if the higher biomass treatment would overtake the bare fallow moisture levels in a normal year.

The legacy effect of the various forms of ground cover will be monitored throughout the 2020 season.

Summer weed results (soil water) are not included due to the uneven nature of summer weed establishment that was not picked up by the soil neutron probe.

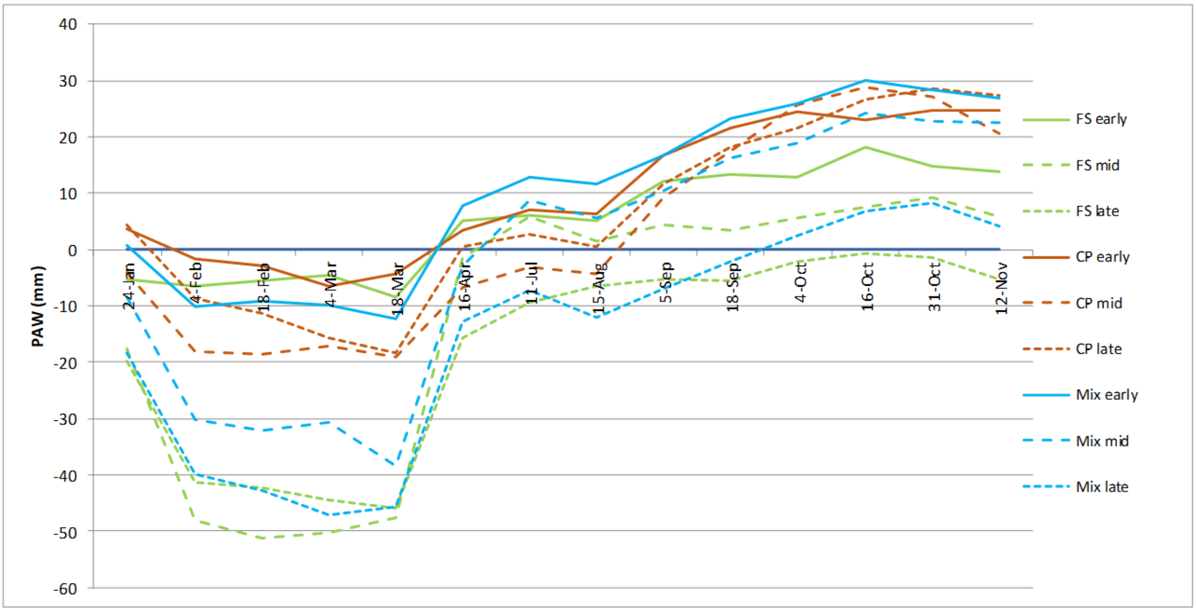

Figure 1. Individual treatment effects on soil water accumulation (+/- mm PAW) compared with the bare ground control at Canowindra NSW

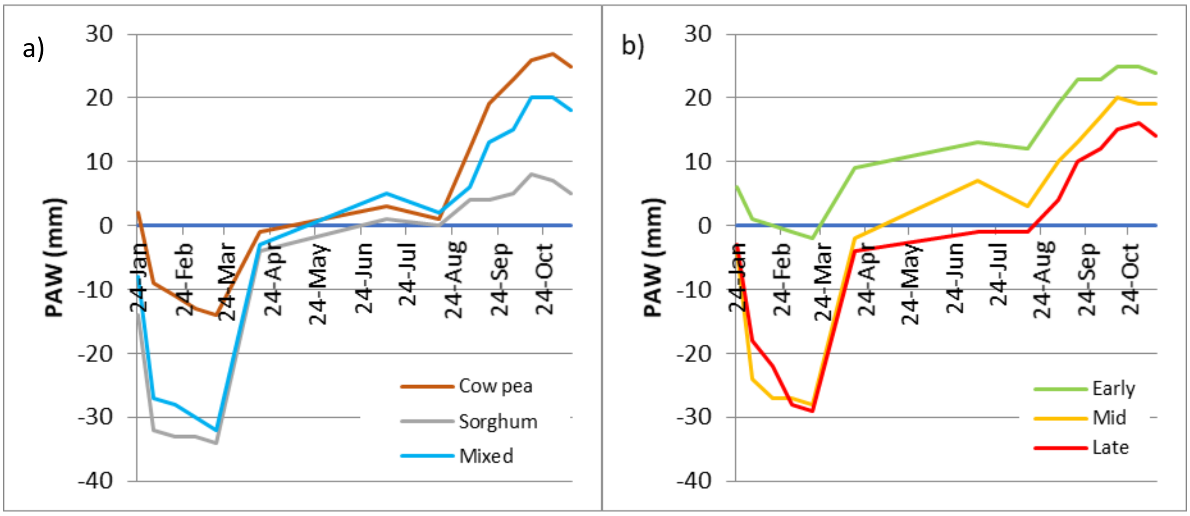

Figure 2. Main effects of cover crop-type (a) and spray-out timing (b) on soil water accumulation compared with the bare ground control at Canowindra NSW.

Predicta® B results – (stubble and soil pathogens)

Canowindra site

Diseases that were significantly affected by the various cover crops and spray out timings included: Take all; *Pythium clade* F; *Pyrenophora tritici repentis*; *Pratylenchus neglectus*; *Macrophomina phaseolina* and *Fusarium* spp. Results will be included in a separate report

Parkes site

Diseases that were significantly affected by the various cover crops and spray out timings included: Take all; *Pythium clade* F; *Pratylenchus thornei*; *Macrophomina phaseolina*; *Didymella pinodes* and *Fusarium* spp.

Grain yield results

Canowindra site

The average grain yield was 1.91 t/ha, and ranged from 1.13 to 2.93 t/ha. Grain yield was affected by crop-type (P<0.001), spray-out timing (P<0.001) but not the interaction between both (P=0.459).

The highest grain yield (2.93 t/ha) was from the bare ground treatment, and on average reduced by 1.4 t/ha, 1.2t/ha, 1.2 t/ha and 0.6 t/ha from the cow pea, forage sorghum, mixed species and summer weed treatments, respectively. Grain yield reduced as spray out timing was delayed with early, mid and late yielding 2.43 t/ha, 1.72 t/ha and 1.33 t/ha, respectively. Interestingly, the cow peas provided little benefit for the following winter cash crop.

Parkes site

The Parkes site was low yielding with an average grain yield of 0.35 t/ha, ranging from 0.07 to 0.71 t/ha. Grain yield was affected by crop type (P<0.001), spray out timing (P=0.003) and the interaction between crop type and spray out timing (P=0.032).

The highest grain yield (0.71 t/ha) was in the control which was weed-free, bare ground, and on average, grain yield reduced by 0.56 t/ha, 0.51 t/ha, 0.33 t/ha and 0.04 t/ha following forage sorghum, mixed species, cow pea and summer weeds, respectively. Compared with the bare ground treatment, grain yield reduced by 0.27 t/ha and 0.39 t/ha following the early and mid-spray out timing, respectively. There was no further grain yield loss between mid and late spray-out timing. Refer to Table 4 for individual effects.

Table 3. Individual treatment results from short fallow cover crop experiment – Canowindra NSW.

Crop type	Spray-out timing	Ground cover biomass (t/ha)	Soil temperature (°C)	Mineral N (kgN/ha)	Total carbon 0–10cm (%)	Total carbon 10–30cm (%)	Wheat grain yield (t/ha)
Bare	Weed-free	0	24.3	321	1.76	0.637	2.93
Cowpea	Early	0.71	24.2	286	1.75	0.608	2.26
	Mid	1.5	23.6	275	1.87	0.623	1.23
	Late	1.73	23.5	266	2	0.675	1.23
Forage sorghum	Early	2.8	21.7	288	1.93	0.683	2.45
	Mid	5.9	18.9	195	2.17	0.595	1.56
	Late	10.8	19.3	245	2.26	0.738	1.13
Mixed species	Early	1.71	22.2	274	2.01	0.615	2.15
	Mid	4.03	19.4	241	2.14	0.55	1.76
	Late	4.51	20	212	2.12	0.72	1.19
Summer weeds	Early	0.1	24.1	343	2.07	0.608	2.84
	Mid	0.51	23.6	316	1.92	0.69	2.33
	Late	2.32	23.8	276	1.95	0.605	1.75
P value		*<0.001*	*<0.001*	*0.03*	*0.15*	*0.907*	*<0.001*
5% Lsd		*1.1*	*1.1*	*80*	*0.36*	*0.236*	*0.5*

Table 4: Individual treatment results from short fallow cover crop experiment – Parkes NSW.

Crop type	Spray-out	Cover Biomass (t/ha)	Soil temperature (°C)	Mineral N (kgN/ha)	Total carbon 0–10cm (%)	Total carbon 10–30cm (%)	Grain yield (t/ha)
Bare	Weed free	0	27.1	153	1.01	0.49	0.71
Cowpea	Early	0.27	27.1	126	1	0.51	0.48
	Mid	0.4	27.3	82	0.99	0.49	0.33
	Late	0.42	27	100	0.95	0.54	0.34
Forage sorghum	Early	0.47	26.5	104	1.02	0.43	0.28
	Mid	1.86	25.8	86	1.12	0.51	0.1
	Late	2.09	26.8	61	1.07	0.57	0.07
Mixed species	Early	0.47	27.2	96	1.01	0.45	0.37
	Mid	1.42	27	84	0.97	0.45	0.15
	Late	0.94	26.1	95	1.08	0.46	0.09
Summer weeds	Early	0.1	27	119	0.97	0.5	0.63
	Mid	0.12	26.9	116	0.1	0.43	0.62
	Late	0.04	27.6	120	1.02	0.46	0.77
P value		*<0.001*	*0.019*	*0.015*	*0.655*	*0.851*	*<0.001*
5% Lsd		*0.754*	*0.9*	*42*	*0.153*	*0.159*	*0.159*

Table 5. Cover crop feed quality results and potential lamb production results – Canowindra.

Crop type	Spray out time	Yield (t DM/ha)	Metabolisable energy (MJ/kg DM)	Crude protein (%)	Liveweight gain (kg/ha) [1]	Value of gain ($/ha) [2]
Cowpea	Early	0.7	10.7	23.3	85	297
	Mid	1.5	10.2	17.6	161	563
	Late	1.7	10.1	17.6	176	617
Forage sorghum	Early	2.8	10.2	14.5	300	1051
	Mid	5.9	10.3	10.2	522	1827
	Late	10.8	11.1	7.9	1062	3716
Mixed species	Early	1.7	11.0	19.9	228	799
	Mid	4.0	10.1	12.7	400	1399
	Late	4.5	10.4	11.3	469	1643

1. Crossbred wether lambs (Border Leicester x Merino or Dorset x Merino), 6 months old, 30 kg live weight utilising 80% of the crop grown.
2. Lamb value of $3.50 per kg.
3. These results are based on feed test results conducted from dry matter samples, sheep were not actually grazed.

Table 6. Cover crop feed quality results and potential lamb production results – Parkes.

Crop type	Spray out time	Yield (t DM/ha)	Metabolisable energy (MJ/kg DM)	Crude protein (%)	Liveweight gain (kg/ha) [1]	Value of gain ($/ha) [2]
Cowpea	Early	0.3	11.1	24.7	37	130
	Mid	0.4	10.0	23.0	40	138
	Late	0.4	10.9	20.3	53	185
Forage sorghum	Early	0.5	10.5	12.6	50	176
	Mid	1.9	11.0	12.8	234	818
	Late	2.1	10.5	9.7	218	761
Mixed species	Early	0.5	10.7	16.2	56	196
	Mid	1.4	10.9	13.9	177	619
	Late	0.9	10.6	11.3	100	352

1. Crossbred wether lambs (Border Leicester x Merino or Dorset x Merino), 6 months old, 30 kg live weight utilising 80% of the crop grown.
2. Lamb value of $3.50 per kg.
3. These results are based on feed test results conducted from dry matter samples; sheep were not actually grazed.

Conclusion

Summer cover crops provide a series of pros and cons for the following winter cash crop. Individual paddock goals, enterprise mix, rainfall and commodity prices will ultimately determine if the pros outweigh the cons. There needs to be a clear understanding of how the cover crop will integrate and benefit the broader farming system.

Soil water recharge following a cover crop is much quicker than bare ground, yet a soil water deficit would occur if no rain falls after cover crop termination. Even in a wet year, there is likely to be a nitrogen deficit for the following winter cash crop that would require correcting with additional nitrogen fertiliser. Presumably, as total carbon % increases, the reliance on supplementary nitrogen could reduce over time with an understanding this will take a number of years.

Grain only cropping operations with short fallows (6 month) are likely to increase the financial risk profile when growing summer cover crops, as yield was reduced at both experiment sites following a cover crop compared with bare ground. Management techniques that retain stubbles and control summer weeds are still considered best practise, as no additional water is used to grow the biomass. However, the use of cover crops as a 'one off' technique to protect the soil from wind or water erosion in low ground cover scenario's may be warranted but considered a 'one off' rather than regular annual management operation.

Conversely, mixed farming enterprises have good reason to capitalise on the increased biomass of a summer cover crop given the current prices for red meat (Tables 5 and 6). According to these results, the grazing value would more than compensate for the winter crop grain yield penalty. Nutrients such as nitrogen would need to be adequate to support such a high output system, however the additional income from the livestock enterprise would compensate for the additional nutritional expenses.

Whilst not absolute, disc seeders are an integral part of the cover cropping system as they improve crop establishment in rapidly drying soils (associated with summer plantings) and provide for the high trash flow requirements of the cover crop system. A patchy cover crop will be no better than a weedy fallow, so crop establishment is an important factor. Consideration needs to be given to seeding depth, particularly for multi-species mixes as the seed size range within the mix will determine the potential seeding depth. For example, millet needs to be sown shallow, but forage sorghum and cow peas can be sown much deeper.

The improved rate of soil water recharge was interesting, and the legacy effects will be monitored throughout the 2020 season to evaluate if the higher biomass treatments overtake the bare fallow.

A separate report will detail results from summer cover crops in LONG fallow paddock scenarios.

Useful resources

https://grdc.com.au/resources-and-publications/all-publications/publications/2019/blackleg-management-guide

References

Edwards J (2006). Forage options for summer and autumn. NSW Department of Primary Industries. Online at : https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0018/100179/forage-options-for-summer-and-autumn.pdf

McMaster C, Graham N, Kirkegaard J, Hunt J and Menz I (2015). "Buying a spring" – the water and nitrogen cost of poor fallow weed control. Proceedings of the 17th ASA Conference.

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Innovative approaches to subsoil liming and management

Dr Guangdi Li, NSW Department of Primary Industries

Key words

soil acidity, lime, organic amendments, deep ripping, pH, exchangeable aluminium

GRDC code

DAN00206

Take home messages

- Lime is the most effective ameliorant to increase soil pH
- Organic materials are not as effective as lime in changing pH, but reduced exchangeable Al% significantly
- Applying lime with organic materials could facilitate downward movement of alkalinity
- However, over a longer term applying large amounts of organic materials could acidify soil due to nitrification.

Introduction

Subsoil acidity is a major constraint to ongoing productivity in the high rainfall zone (500–800 mm) of south-eastern Australia (Scott et al., 2000). Approximately 50% of Australia's agriculture zone (~50 M ha) has a surface soil pH < 5.5 in calcium chloride (pH, hereafter) and half of this area also has subsoil acidity (SoE, 2011). In southern NSW, there are 13.5 M ha of agricultural soils exhibiting a subsurface soil acidity problem (Dolling et al., 2001). The agricultural production loss from soil acidity is estimated as $387 million in NSW (SoE, 2011).

The surface application of lime is a widely accepted practice to combat soil acidification at the surface (Scott et al., 2000; Ryan, 2018). However, lime moves very slowly down the soil profile so subsoil acidity will only be ameliorated after decades of regular lime application at appropriate rates to the soil surface (Li et al., 2019). Research from a long-term field experiment, known as MASTER, showed that pH increased at 0.04 pH units per year at 10-20 cm by maintaining pH above 5.5 at 0-10 cm with adequate lime application (Li et al., 2019). However, the current commercial recommended rate of 2.5 t/ha every 6-10 years is not enough to stop further soil acidification, as most of the alkalinity added is consumed in the topsoil with very little remaining to counteract subsoil acidification. Results from two soil surveys conducted in 2006 and in 2015-2017 in southern NSW showed that soil acidity is continuing to move further down the soil profile even where lime application is applied regularly over the 10 year period (Burns and Norton, 2018). We are acidifying our soils under contemporary minimum tillage farming systems.

The challenge is how to stop further soil acidification and speed up amelioration of subsoil acidity. The research questions are:

- Does deep ripping speed up amelioration of subsoil acidity? What is the rate of amelioration under deep ripping? Farmers need this information to make decisions on their capital investment (e.g. lime) and to estimate the economic return from the further investment for the cost of the deep ripping
- What is the role of organic materials in the amelioration of soil acidity? What types of organic materials are effective and what rates are required to achieve fast movement of alkalinity down

the soil profile? Farmers need to be informed to strategically implement soil organic amendments to maximise profits in a longer term

- Is deep tillage a viable option to fix subsoil acidity? Farmers need to know the benefit of a "quick" fix of mixing soil with soil amendments by vigorous tillage compared with the perceived detrimental damage to soil structure and the environment in the short, medium and long term.

Methodology

A national coordinated project "Innovative approaches to managing subsoil acidity in the southern grain region" funded by GRDC (DAN00206) is testing whether aggressive application methods such as deep placement of lime and/or organic materials will achieve rapid changes to pH at depth.

A series of lab incubation studies and soil column experiments have been conducted under controlled conditions to

a) Compare the effectiveness of a range of inorganic and organic amendments, and their combinations, to ameliorate soil acidity; and

b) Optimise the application rates and application depth in soil profiles to identify the most effective soil amendments.

Four small plot field experiments and eight large-scale on-farm field experiments have been set up across southern NSW to north west Victoria to test optimum rates of the most effective soil amendments at various soil depths to validate their effectiveness under field conditions.

The inorganic amendments tested include lime, dolomite, magnesium silicate (MgSi), calcium nitrate, reactive phosphate rock (RPR), gypsum etc. The organic amendments tested include plant residues/materials (such as lucerne hay, pea hay, cereal crop straw, garden composts), animal wastes (such as poultry litters, dairy compost, sheep manure) as well as biochar, biosolids and k-humates.

Key results

Magnesium silicate

Magnesium silicate (MgSi) is a novel product that has potential as a soil ameliorant to elevate soil pH. The neutralising value of pure MgSi is estimated as 1.4 times higher than that of limestone.

A blended product of MgSi (70% Doonba dunite and 30% F70 superfine lime) with neutralising value about 100% was used at the Holbrook site from 2015-2017. Results showed that both deep liming and deep MgSi treatments increased soil pH significantly at the 20–30 cm depth (P<0.001) where soil amendments were applied compared with the no amendment treatment, three years after treatments were implemented (Figure 1). However, there was no significant difference in soil pH between deep liming and deep MgSi treatments at either 10–20 cm or 20–30 cm.

MgSi reduced exchangeable Al% (Al as percentage of effective cation exchange capacity) significantly at 10–20 cm (P<0.01) and 20–30 cm (P<0.05, Figure 2). The exchangeable Al% tended to be lower in the deep MgSi treatment than that in the deep liming treatment, but no significant difference was detected. Further research is required to explore whether MgSi is more efficient in decreasing Al toxicity than lime as claimed by Castro and Crusciol (2013).

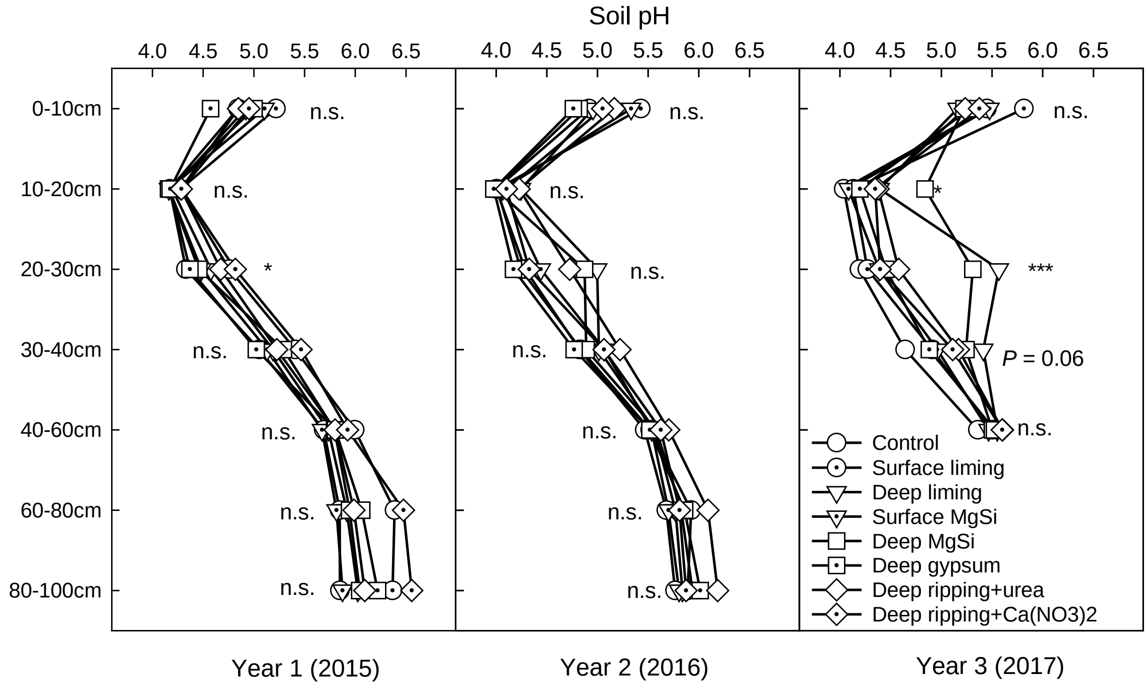

Figure 1. Soil pH in $CaCl_2$ under different soil amendment treatments in autumn in years 1-3 at the Holbrook site.

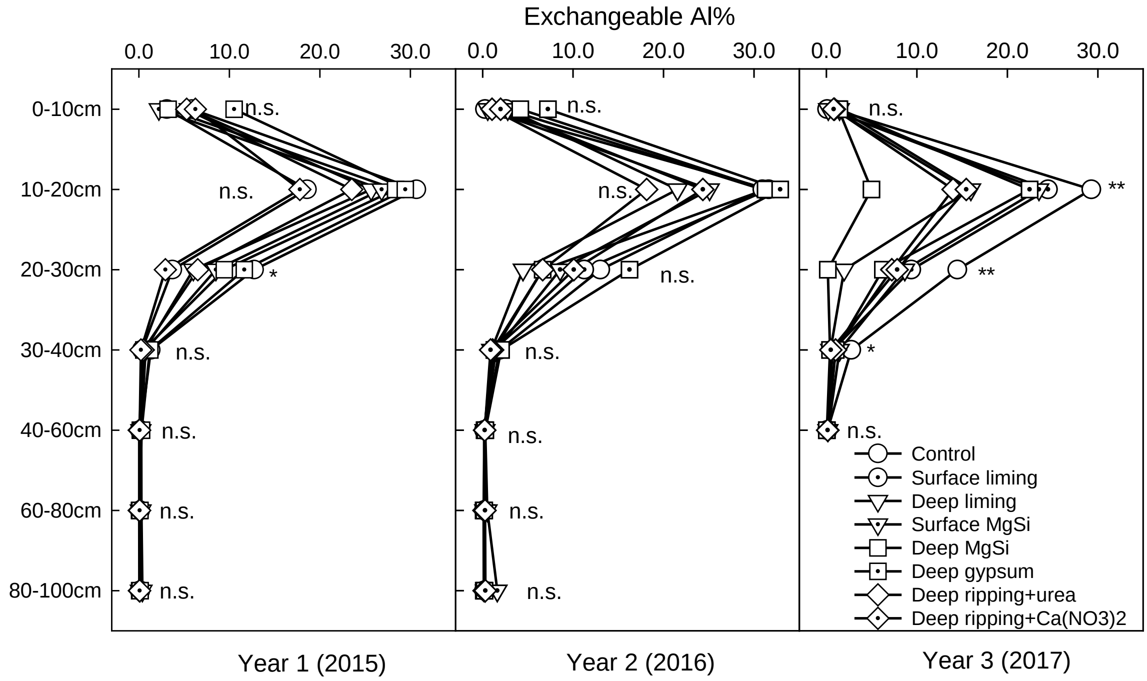

Figure 2. Soil exchangeable Al% under different soil amendment treatments in autumn in years 1-3 at the Holbrook site.

Calcium nitrate

Calcium nitrate supplies plants with nitrogen in the form of nitrate, which would promote great anion uptake, leading to the release of OH^- ions into the rhizosphere and thus increase of rhizosphere pH. There is potential for effect of root-induced alkalization in the rhizosphere to expand to ameliorate acidity in the bulk soil beyond the rhizosphere (Conyers et al.,2011; Tang et al., 2013).

Results from a pot experiment conducted by the La Trobe University researchers involved in this project showed that calcium nitrate not only increased rhizosphere pH, but it also increased bulk soil pH by 0.25 units in the Rutherglen and Bethungra soils, compared with those treated with urea over a short period (28 days)(Figure 3). Calcium nitrate addition also increased shoot biomass by 20% compared with urea in Rutherglen and Bethungra soils, but there were no treatment differences in shoot biomass in Frankston, Holbrook and Welshpool soils (data not shown). Results from a field experiment conducted at Holbrook showed that there was no significant difference in either pH or exchangeable Al between sources of N (urea vs calcium nitrate) over 3 years (Figure 1 and Figure 2). Thus, there is limited benefit to change of soil pH in the bulk soil over a long-term.

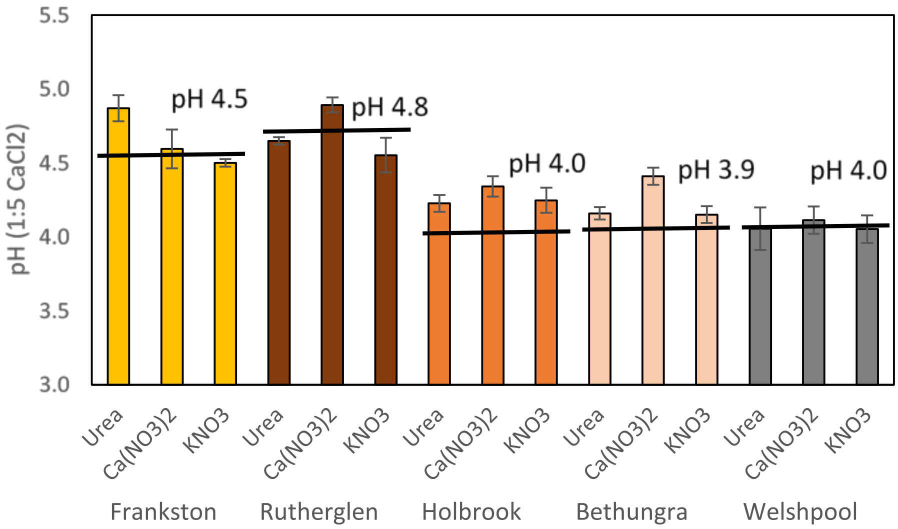

Figure 3. Bulk soil pH for soils treated with urea, calcium nitrate [$Ca(NO_3)_2$] and slow release KNO_3. Bars indicate standard errors of the mean (n=3). Black solid lines indicate initial soil pH

Reactive phosphate rock

Reactive phosphate rock (RPR) contains slow release P with reasonable high alkalinity that could be used as a P source as well as a soil ameliorant for soil acidity. At the Rutherglen site, RPR at low (4t/ha) and high rates (8t/ha) increased canola grain yield by 0.5 t/ha compared with the limed control in year 1 (Figure 4), which was similar to the treatment with high rate of lucerne hay pellets (15t/ha). There were no yield responses with any other soil amendments (Figure 4).

Deep placement of organic materials may induce manganese toxicity due to enhanced oxygen consumption by microorganisms and poor aeration at depth. Positive results of RPR and lucerne hay pellets on yield may be due to improved nutrition and pH increase, indicating that interactions of these factors need to be investigated for growers to realise efficiency gains of amendment additions at depth.

In the second growing season, treatment effects were observed visually in the first 4 weeks of growth. Plants in the untreated control and surface liming treatments were small and spindly, whilst plants in deep amended treatments appeared healthier. However, due to harsh conditions during the 2018 growing season, the early visual symptoms did not carry through, resulting in non-significant differences between treatments at harvest. Despite this poor agronomic result in 2018, the results from soil sampling indicated that, in general, liming agents applied at the start of the

2017 season were maintaining positive effects on soil pH and exchangeable aluminium concentrations, which should improve plant growth under better seasonal conditions in future years.

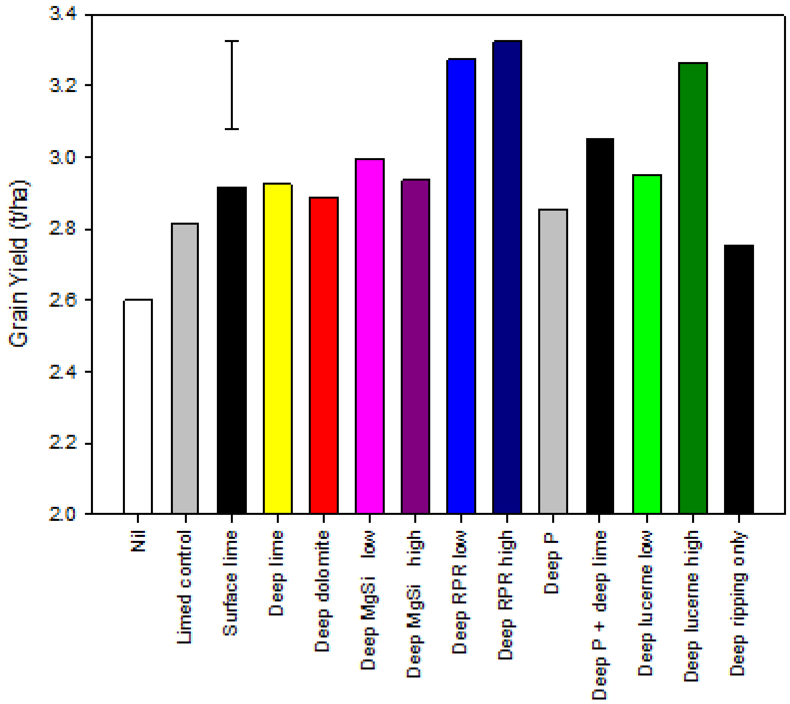

Figure 4. Harvest yield of canola (t/ha) for amendment treatments at Rutherglen site. Data are treatment means of 3 replicates. Bar indicates l.s.d. (P=0.05).

Organic materials

Organic materials can have a liming effect and thus may also be used as soil ameliorants to manage acid soils. However, the magnitude of any pH rise varies between amendments is dependent on their ash alkalinity and the concentration of excess base cations, which is reflective of the concentration of stored organic acid anions (Tang and Yu, 1999).

Lucerne hay pellets were used as a soil amendment at a rate of 15t/ha throughout all field experiments. At the Cootamundra site, there was no difference in soil pH between treatments at any depth in year 1 prior to treatments being imposed. In autumn 2017, one year after treatments were applied, surface liming increased pH to 5.9 at 0-10cm. The deep limed treatment with and without lucerne pellets significantly increased soil pH at 10-20cm and 20-30cm as expected. A similar trend was observed in 2018 (Figure 5).

The deep liming treatments, either with or without lucerne hay pellets, reduced exchangeable Al to less than 2% in 2017 and 3% in 2018 at 10-30cm (Figure 6). Although lucerne hay pellets did not increase soil pH as much as expected, it did reduce exchangeable Al% significantly at 10–20 cm and 20–30 cm (Figure 3) compared with the no amendment treatment. This is likely to be the result of the soluble organic molecules from lucerne hay pellets combining with active Al^{3+} to form insoluble hydroxy-Al compounds (Haynes and Mokolobate, 2001), which would reduce Al toxicity to plant growth. The exchangeable Al remained high in the 10-30cm depths under ripping only and surface lime treatments. The nil amendment treatment had the highest exchangeable Al at all three depths at 0-30cm.

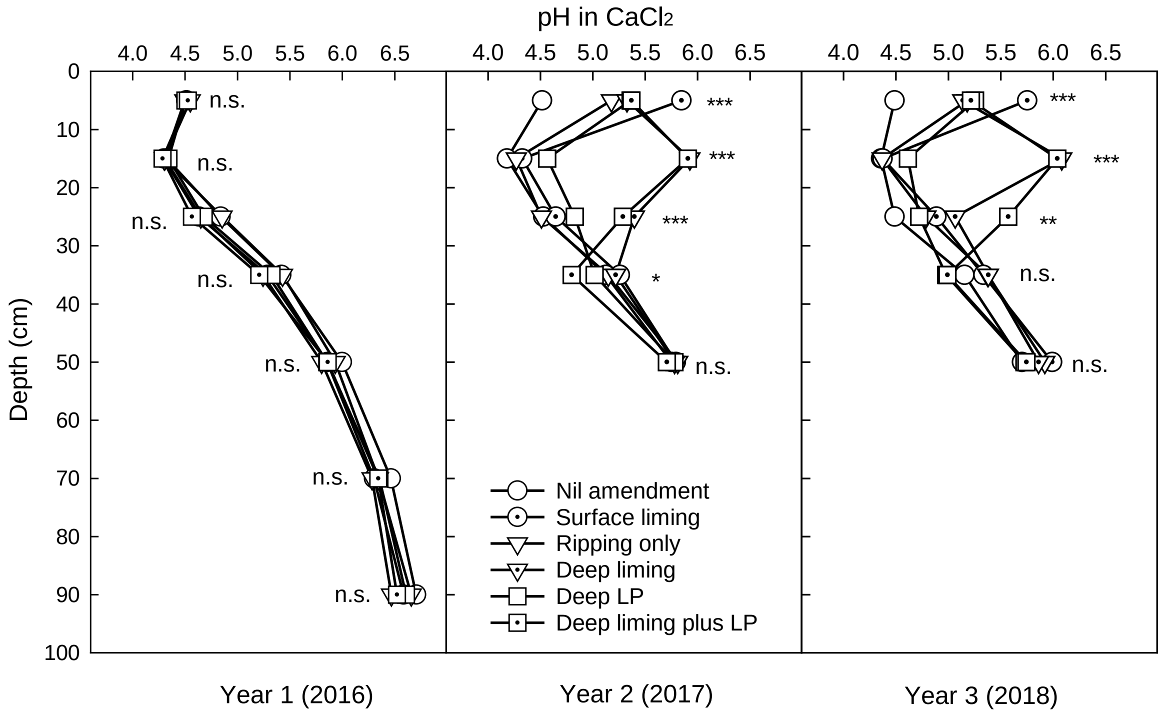

Figure 5. Soil pH in $CaCl_2$ under different soil amendment treatments in autumn in years 1–3 at the Cootamundra site. n.s., not significant.

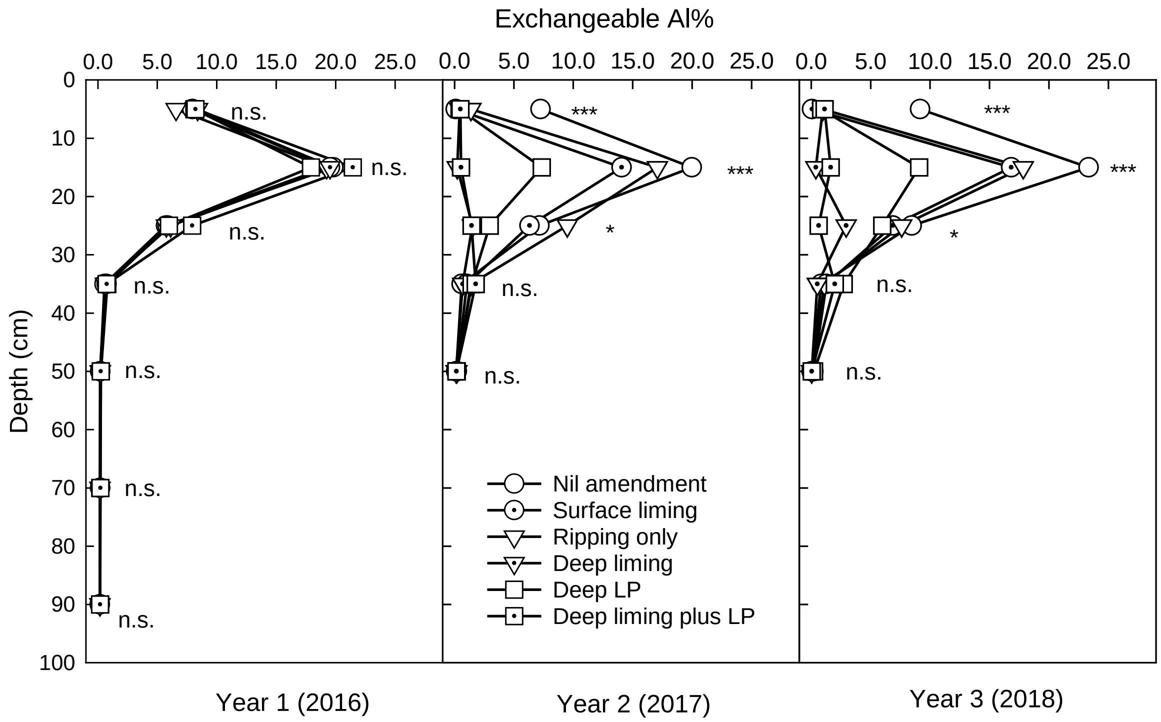

Figure 6. Soil exchangeable Al% under different soil amendment treatments in autumn in years 1–3 at the Cootamundra site. n.s., not significant.

A range of organic materials with and without lime were tested in the field at the Holbrook site. At anthesis in year 1, the lucerne hay pellet treatment had the highest dry matter (DM) (9.6 t/ha), whereas the biochar with lime and wheat straw treatment had the lowest (5.2 t/ha) (Figure 7). Both poultry litter treatments had more than 8 t/ha of DM. At harvest, grain yield followed a similar trend to anthesis DM. The lucerne hay pellet treatment had the highest grain yield, close to 2 t/ha, followed by the poultry litter with lime treatment, whereas the lime treatment had similar grain yield to the control treatment (Figure 7). At seedling stage through to anthesis, the nitrogen content in plant tissues were higher under lucerne pellets and poultry litter treatments due to their high nitrogen content in the products. It is concluded that in the first year after treatments were implemented, crops responded to increased nutrient levels, particularly nitrogen, rather than to the amelioration of soil acidity.

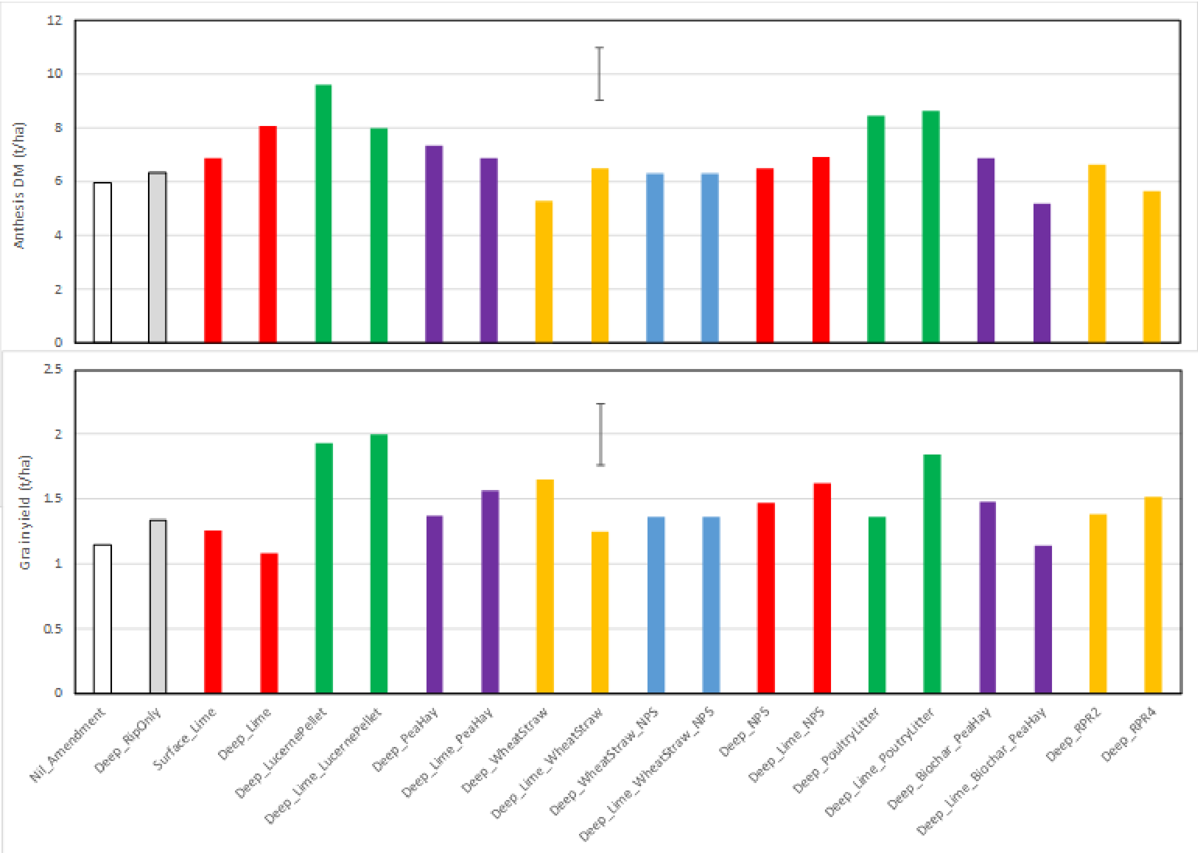

Figure 7. Crop dry matter (DM) at anthesis and grain yield at harvest under different treatments at the Holbrook site. The paired treatments with same colour are with and without deep liming except for the first 4 treatments on the left.

Lime + organic materials

The mineralization of organic materials is an alkaline process that increases soil pH, but the nitrification is an acid process that decreases soil pH (Helyar, 1976). Butterly et al. (2013) showed that plant residues can produce alkalinity below the layer applied. This is due to the leaching of organic compounds and organic acids, with any subsequent effect on pH being a function of ammonification, nitrification, and release of alkalinity by decarboxylation further down the profile.

The addition of lime with plant residues can generate alkalinity below the amended layer, create favourable pH gradients and may facilitate the downward movement of alkalinity from lime as demonstrated in a leaching experiment (Figure 8). Lucerne residues showed the greatest short-term increase in pH one month after incubation, but re-acidified soil after three months of incubation (Figure 8).

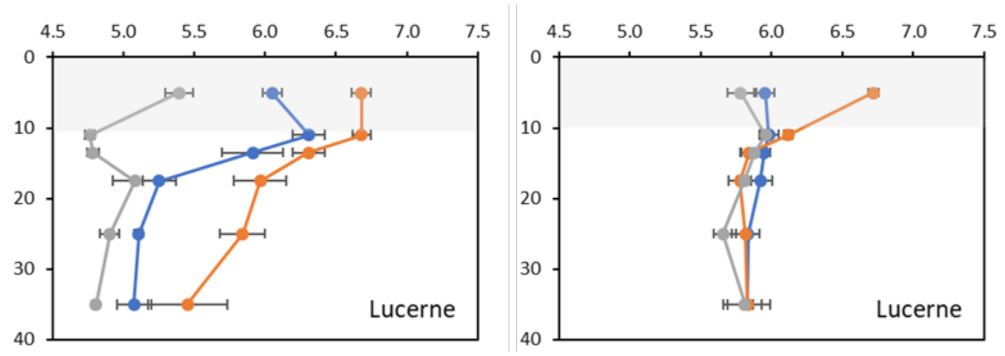

Figure 8. Soil pH profile in soil columns 1 month (left) and 3 months (right) after amendment (0-10 cm, shaded grey) with lucerne residues (blue line), lucerne + lime (orange line) and control (grey lines) (Clayton Butterly, La Trobe University, unpublished data)

In field conditions, however, the addition of large amount of organic materials could acidify soil further over the longer term. Results from an intensive soil grid sampling at the long-term site at Cootamundra showed that soil pH beyond the ripping depth was lower under lucerne hay pellet treatments, with and without lime, compared with that under surface liming and deep liming treatments, four years after treatments were implemented (Figure 9).

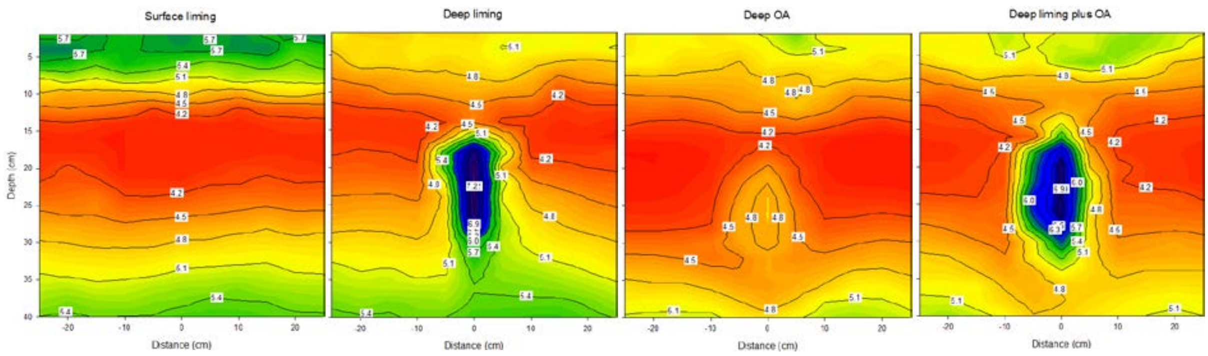

Figure 9. The spatial distribution of soil pH in $CaCl_2$ in soil profile with (a) surface liming, (b) deep liming, (c) deep organic amendment, and (d) deep liming plus organic amendment Four years after treatments were implemented at the Cootamundra site in 2019

Summary

Subsoil acidity is difficult to manage. It will take decades for the current lime programs that apply lime the surface 0-10 cm layer regularly with appropriate rates aiming to ameliorate subsoil acidity. Deep placement of lime could speed up the amelioration process compared with surface liming. Given the nature of the ripping operation (Poile et al., 2012), the soil disturbance (and so the volume of soil treated) is restricted into a narrow slot. This is usually just 5-8 cm wide depending on the shape of the tyne used. This leaves large volumes of untreated soil. In addition, the vertical movement of lime is very slow and the lateral movement of lime is minimal (almost negligible). Therefore, it is unlikely that the constraint of subsoil acidity could be overcome in a short time frame. Further work is warranted to study whether a full tillage at depth is a viable option to amend the subsoil acidity problem. Growers want to know the economic benefit of the “quick” fix of mixing soil and soil amendment by vigorous tillage. They also want clarification on the perceived detrimental effects on soil structure and on the environment in the short, medium and long term.

A range of inorganic and organic soil amendments have been tested in a number of lab incubation studies and soil column experiments in glasshouse. Promising novel materials have been implemented in a number of field experiments and monitored over 2-3 growing seasons. The key findings are summarised below:

- Lime is the most effective ameliorant to increase soil pH
  - MgSi is potentially more efficient than lime in decreasing Al toxicity
  - Calcium nitrate can increase pH of the rhizosphere, but the effect on bulk soil pH is limited
  - Reactive phosphate rock has a positive effect on crop yield, probably due to improved nutrition. Its role in increasing pH needs further investigation.
- Organic materials are not as effective as lime in increasing pH, but reduce exchangeable Al% significantly
  - The mineralisation of organic matter increases soil pH in a short time frame
  - However the nitrification would re-acidify soil and decrease soil pH in the medium to long term.
- The combination of lime with organic materials could facilitate downward movement of alkalinity from the lime in the short term.
  - However, applying large amounts of organic materials could acidify soil due to nitrification over a longer term.

Acknowledgements

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References

Burns HM and Norton MR (2018) Subsurface acidity threatens central and southern NSW cropping areas. In 'National Soils Conference 2018'. Canberra. (Soil Science Australia). Web site https://www.soilscienceaustralia.com.au/publications/national-conferences.

Butterly C, Baldock J, Tang C (2013) The contribution of crop residues to changes in soil pH under field conditions. Plant and Soil 366, 185-198.

Castro GSA and Crusciol CAC (2013) Effects of superficial liming and silicate application on soil fertility and crop yield under rotation. Geoderma 195-196, 234-242.

Conyers MK, Tang CX, Poile GJ, Liu D, Chen DL, Nuruzzaman Z (2011) A combination of biological activity and the nitrate form of nitrogen can be used to ameliorate subsurface soil acidity under dryland wheat farming. Plant and Soil 348, 155-166.

Dolling PJ, Moody P, Noble A, Helyar KR, Hughes B, Reuter D, Sparrow L (2001) 'Soil acidity and acidification.' (National Land and Water Resources Audit: Commonwealth of Australia).

Haynes RJ and Mokolobate MS (2001) Amelioration of Al toxicity and P deficiency in acid soils by additions of organic residues: a critical review of the phenomenon and the mechanisms involved. Nutrient Cycling in Agroecosystems 59, 47-63.

Helyar KR (1976) Nitrogen cycling and soil acidification. Journal of the Australian Institute of Agricultural Science 42, 217-221.

Li GD, Conyers MK, Helyar KR, Lisle CJ, Poile GJ, Cullis BR (2019) Long-term surface application of lime ameliorates subsurface soil acidity in the mixed farming zone of south-eastern Australia. Geoderma 338, 236-246.

Poile G, Oates A, Moroni S, Lowrie R, Conyers M, Swan T, Peoples M, Angus J, Kirkegaard J, Condon K, Durham K, Breust P, Armstrong R, Nuttall J (2012) Canola and subsoil constraints - Technical Bulletin. (Eds H Burns and T Nugent) p. 12. Available at https://www.csu.edu.au/__data/assets/pdf_file/0003/922764/Canola_-and-_subsoil_constraints.pdf.

Ryan P (2018) Assessing the role of genetics for improving the potential yield of Australia's major grain crops on acid soils. Crop & Pasture Science 69, 242-264.

Scott BJ, Ridley AM, Conyers MK (2000) Management of soil acidity in long-term pastures of south-eastern Australia: a review. Australian Journal of Experimental Agriculture 40, 1173-1198.

SoE (2011) 2.2.5 Soil acidification. In 'Australia state of the environment 2011' pp. 287-293. (State of the Environment 2011 Committee: Canberra).

Tang C and Yu Q (1999) Impact of chemical composition of legume residues and initial soil pH on pH change of a soil after residue incorporation. Plant and Soil 215, 29-38.

Tang C, Weligama C, Sale P (2013) Subsurface soil acidification in farming systems: its possible causes and management options. In 'Molecular Environmental Soil Science' pp. 389-412. (Springer).

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Mapping soil properties and their impact on yield - combining Dual EM, gamma radiometrics, elevation and soil colour to select sampling sites to predict soil properties and investigate their impact on yield across the paddock

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Key words

digital soil mapping, soil constraints, yield analysis, proximal sensing, EM survey

Take home messages

- Although EM surveys are a cost-effective tool to map variation in topsoil and subsoil properties, they do not show which soil properties are causing the variation
- Digital soil mapping can create maps of soil properties that can be used to investigate spatial patterns of yield limiting factors at a resolution as fine as a few hectares in a few thousand hectares
- Experience has shown that only some yield-limiting soil factors can be changed, we believe there is value in understanding whether yield is limited by underlying soil properties or by management
- At this stage soil samples are required to map soil properties.

Glossary

Covariates in digital soil mapping are the spatial properties that are used to predict the pattern of soil properties between the points where the soil is sampled. Covariates include EM survey, soil colour, digital elevation model.

Kriging is a statistical technique used to create surfaces from point data using the variation in the data set to estimate how much to smooth the fitted surface.

Multivariate linear regression is a linear equation in which multiple factors are used to predict a soil property. A general equation is: *prediction= a +b*covariate1 +c*covariate2+…..*

Machine learning builds mathematical models without specific instructions.

Proximal sensing is the collection of soil data using instruments that are close to the soil, but do not rely on soil contact, as opposed to remote sensing where the sensors are metres to kilometres from the site.

Regression kriging predicts soil properties using regression and kriging the difference between measured and predicted values. A general equation is:
prediction = trend predicted using regression + residual predicted using kriging

Surface refers to the spatial pattern of a particular variate across an area. E.g. a map of the depth at which the critical value of 10% exchangeable sodium (ESP) was reached .

Introduction

There have been many improvements in the availability of data and in the statistical techniques used to generate digital soil maps over the past 20 years (Minasny and McBratney, 2015). The data improvements have included relatively widespread availability of measures of landscape variation, such as satellite images and digital elevation models, and on farm measures of variation in the form of electromagnetic induction (EM) and yield variation from yield maps. The statistical techniques have progressed from multivariate linear regression through regression kriging (Odeh et al., 1995) and machine learning with kriging of residuals. These models can be used to make 3d predictions of soil properties. To date, digital soil maps have been produced predominantly by researchers and government agencies (Minasny and McBratney, 2015).

The agronomic value of maps of predicted soil properties can be tested by evaluating the correlation between these predictions and crop yield. The project we conducted was essentially an evaluation of the process of combining covariate data with measured soil properties to create digital maps of soil properties and then evaluating the correlation between the predicted soil properties and crop yield.

Methods

The project was conducted on an approximately 2,000 ha irrigation development on Cubbie Station, a large cotton farm in south western Queensland. The data used were a proximal sensing survey of electromagnetic induction, gamma radiometric and elevation; records of cut and fill, and a bare soil redness index from the Landsat 5 satellite. This data was combined to create a covariate database, and then used to direct the sampling of 70 soil cores at four depths (0-30, 30-60, 60-100, 100-140 cm) which were analysed in the laboratory for pH (1:5 $CaCl_2$), exchangeable cations, EC and texture (sand, silt, clay). Relationships between the laboratory measured properties and the covariate dataset were investigated and used to create continuous surfaces of each property at the four depths across the study area (Figure 1).

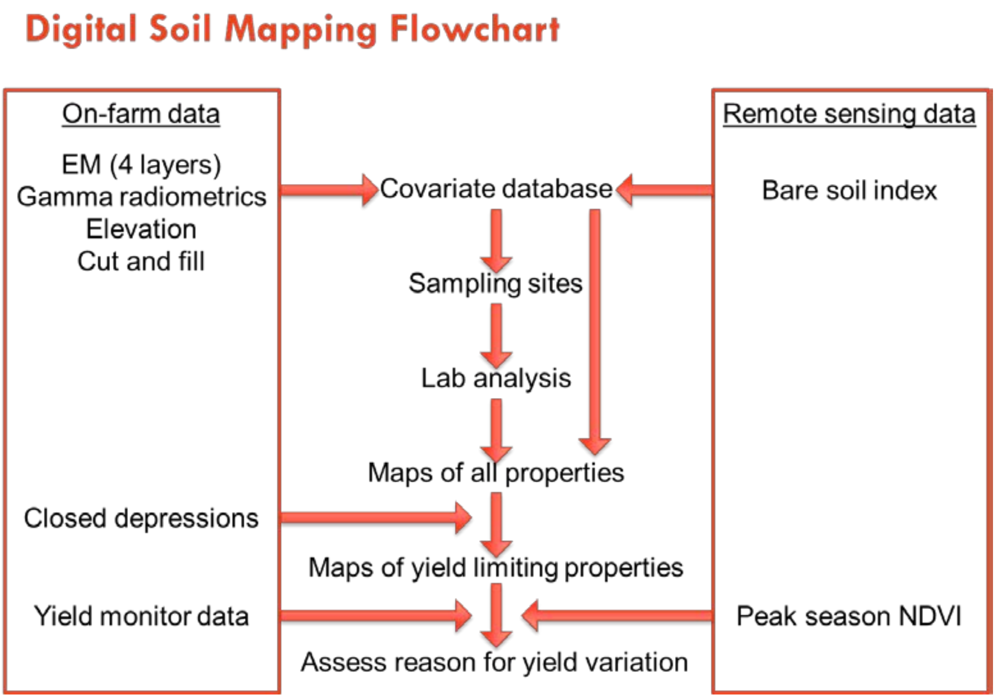

Figure 1. Process used to assess soil reasons for yield variation using digital soil mapping

The potential effect of soil properties on crop growth was assessed by surfaces of the depth to selected critical values. The critical values used were; ESP of 10%; electrical conductivity of saturated extract (ECe) of 10 dS/m; and $pHCaCl_2$ of 8. Correlations between modelled soil properties and cotton lint yield for the 2016- 17 growing season and satellite borne vegetation indices for five years in total were investigated.

Results and discussion

We will describe patterns of 3 of the 9 soil properties that we mapped. These are pH, salinity measured as ECe and sodicity measured as exchangeable sodium percentage (ESP) selected on the basis that there is a body of knowledge indicating a reasonably direct effect of these properties on plant growth. Soil pH was very consistent across the 70 sites assessed (Figure 2). This indicates that soil maps are unlikely to show a spatial effect of pH on crop growth and yield. Salinity measured as ECe was low and uniform in the surface to 30 cm layer and increased and became more variable with depth. This pattern indicates that there may be variation in soil properties that affects plant growth and yield. Average ESP doubled between the 0 to 30 and 30 to 60 cm layer and increased a further 50% to the 60 to 100 cm layer. The coefficient of variation (standard deviation divided by mean) decreased from 33% in the surface to 30 cm layer, to 26% in the 100 to 140 cm layer. The rapid increase in ESP with depth and moderately large variation indicates that there it is a likely contributor to crop yield variability.

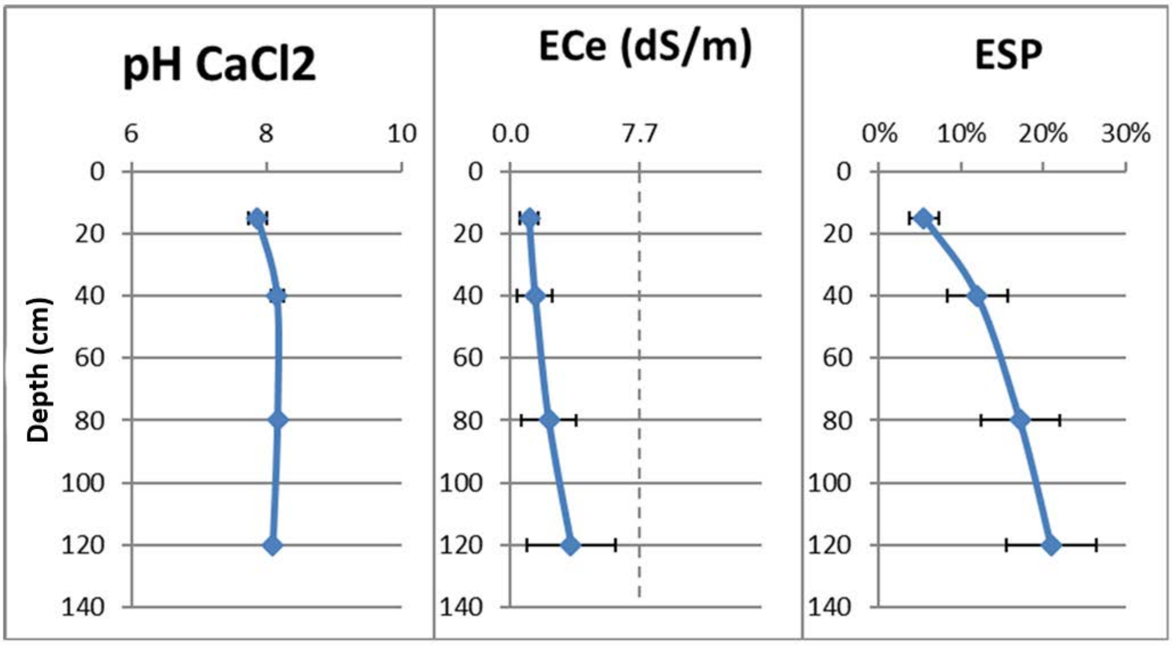

Figure 2. pH ($CaCl_2$), ECe (dS/m) and ESP (%) average and standard deviation of 3 selected properties at 4 depths in 70 sites across more than 2,000 ha of Cubbie Station

The depth to critical soil chemistry values found that the average depth to ECe of 10 dS/m was greater than 140 cm, while the average depth to ESP of 10% was shallower than 50 cm. There was substantial variation over relatively short distances in the depth to critical ESP (Figure 3). A local correlation was used to quantify the relationship between the variation in depth to ESP and yield. In summary, the boxplot in Figure 3 indicates that there was a substantial yield difference between areas where the depth to 10% ESP was shallower than 25 cm and all other depths. This is encouraging in that it indicates that there is potential to increase yield by lowering ESP of the surface 15 cm rather than the whole profile.

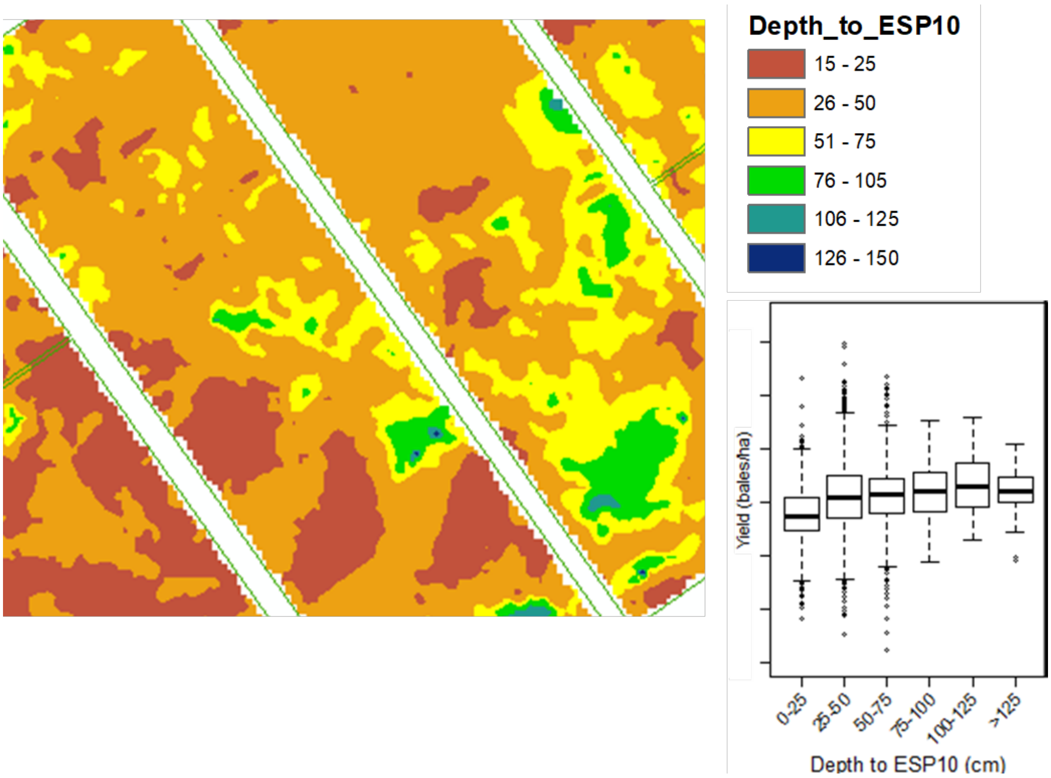

Figure 3. Surface of depth to 10% ESP and boxplot of the correlation between depth to ESP and cotton yield

The correlation between mapped soil properties and crop yield was investigated further by using machine learning to predict the yield of each 20 m by 20 m pixel across the area mapped as dependent on the depth to ESP >10%, depth of ECe >10 dS/m, depth of closed depressions, depth of cut and fill and distance from head ditch. By artificially removing one constraint from the regression we obtained an indication of the yield difference attributed to each constraint. This is demonstrated for closed depressions in Figure 4.

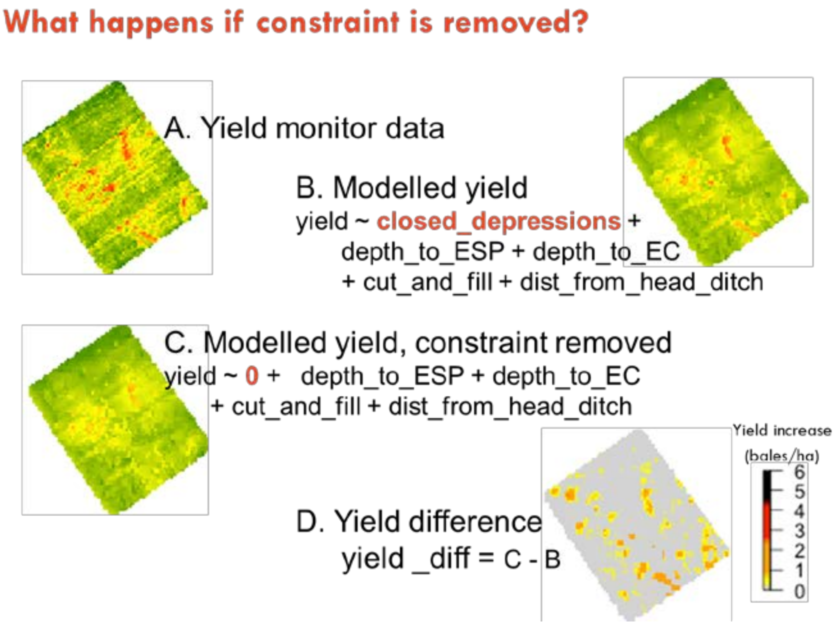

Figure 4. Conceptual model of process to quantify the potential yield benefit of removing yield constraint of closed depressions

Conclusions

- This project demonstrates that while digital soil maps are not an end in themselves, they can be used in association with yield maps to quantify the yield cost of soil constraints.
- Variation in soil properties can affect yield if there is substantial variation in the property, and substantial areas with values that are both lower and higher than the critical value. This occurred most notably with ESP at this site, while the variation in pH $CaCl_2$ and ECe had a smaller impact on yield variability.
- The relationships between covariates and soil properties appear not to be universal, so soil samples are currently required for each survey project, and the covariates vary between sites in their efficacy at predicting soil properties.

References

Minasny, B. and McBratney, AB (2016). Digital soil mapping: A brief history and some lessons. Geoderma, 264, 301-311.

Odeh, IO, McBratney, AB, and Chittleborough, DJ (1995). Further results on prediction of soil properties from terrain attributes: heterotopic cokriging and regression-kriging. Geoderma, 67(3-4), 215-226.

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Improving Phytophthora root rot resistance in chickpeas through breeding for waterlogging tolerance - implications for diagnosing root health and PREDICTA®B testing

Nicole Dron, NSW DPI Tamworth

Key words

chickpea, waterlogging, resistance breeding, Phytophthora root rot, diagnostics, PREDICTA®B

GRDC code

BLG302 - PhD Project: Improving Phytophthora root rot resistance though waterlogging tolerance in chickpea.

Take home messages

- Waterlogging will increase crop damage from Phytophthora root rot (PRR) including a reduction in rooting depth
- Sowing chickpea varieties with higher levels of PRR resistance (PBA HatTrick⸸ & PBA Seamer⸸) will increase likelihood of survival in the presence of disease and in combination with waterlogging
- Observing chickpea root systems is the best determinant of plant health
- When using PREDICTA®B as an in-crop diagnostic tool, sampling for PRR in chickpea should be conducted approximately 8 days after a waterlogging event when increased levels of *Phytophthora medicaganis* DNA are present in the soil and root tissue.

Background

A link between Phytophthora root rot (PRR) resistance and waterlogging tolerance has been discovered previously in soybean. In chickpea this link has not yet been investigated. In 2010, 2012 and 2016, high in-crop rainfall occurred throughout the season in the PRR affected northern growing region and resulted in observed partial and complete chickpea crop losses. These losses were attributed to a number of issues including: waterlogging, salinity, lodging, Ascochyta blight, Botrytis grey mould and PRR. In undulating paddocks with free draining soil, where regular foliar fungicides could be strategically applied, crops suffered only minor yield penalties. Data collected from PRR yield loss trials (DAN00176, DAQ00186) demonstrated that in the 2016 season, when inoculated treatments were saturated for extended periods, yield loss reached up to 90% of the control in the moderately resistant Australian chickpea cultivar PBA HatTrick⸸ (Table 1). This extent of loss was considerably higher than drier seasons with losses of 33% and 68% in 2014 and 2015, respectively (Table 1). However, it remains unclear as to whether increased yield losses in 2016 can be fully attributed to PRR or occurred in combination with waterlogging. Observations under early and cooler waterlogging events, as seen in 2010, saw extended chickpea survival in the absence of PRR. However, in 2016 extensive damage was recorded which may be related to higher temperatures, later physiological growth stage at the time of waterlogging and/or the presence of the PRR pathogen.

Table 1. Annual rainfall and Phytophthora root rot yield loss trial data from the 2014, 2015 and 2016 seasons for PRR moderately resistant variety PBA HatTrickⓟ*.

Season	Total in-crop rainfall (mm)	PBA HatTrickⓟ yield (t/ha) in absence of PRR infection	PBA HatTrickⓟ % yield loss due to PRR infection
2014	137	2.94	33
2015	194	2.50	68
2016	450	4.02	90

*GRDC updates paper - ‘Phytophthora in chickpea varieties 2016 and 2017 trials –resistance and yield loss’ (Bithell et al., 2018).

The life cycle of most oomycetes, including *Phytophthora medicaginis* which causes PRR in chickpea, consist of two phases each driven by the physical surroundings. The most prolific pathway (outer circle) is induced under high soil moisture (above field capacity) where dormant thick-walled oospore structures produce sac like sporangia containing large numbers of water motile zoospores which are released to infect plants. Zoospores can orientate and move towards the host plant infecting root tissue. The second and direct pathway (inner part of circle) is characterised by the production of a single germ tube from oospores or chlamydospores which also occurs under moist soil conditions. Oospores and chlamydospores are thick walled dormant structures able to survive long periods in adverse soil conditions (highest recorded 10 years). Under waterlogging conditions it is assumed that an influx of zoospores leads to severe PRR disease development. However, germination of Phytophthora spores requires oxygen which is greatly reduced or absent under waterlogging conditions. Oxygen levels are dependent on duration, temperature and soil characteristics. If the waterlogging event is short and water is fast draining, oxygen is not depleted and adequate levels of oxygen remain where Phytophthora species are able to survive and infect host root tissue.

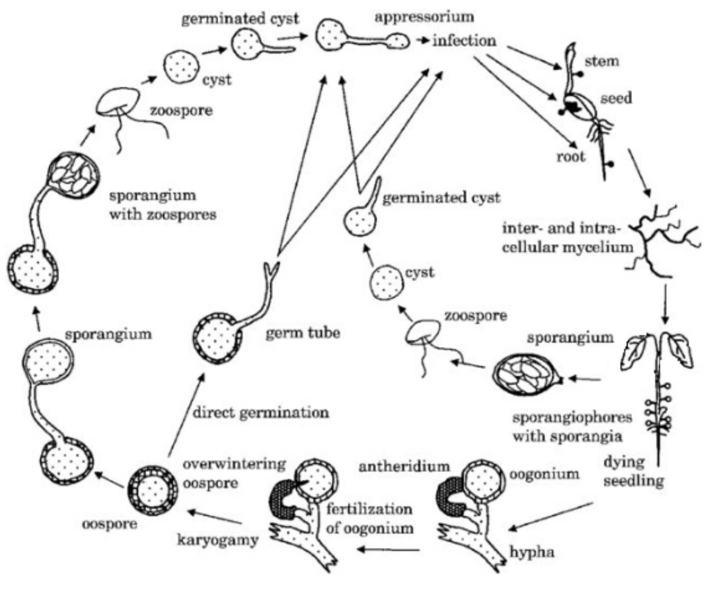

Figure 1. Life cycle of a typical root infecting oomycete *Pythium* and *Phytophthora* species (Van West, Appiah, & Gow, 2003)

Ongoing breeding and pathology efforts aim to understand and improve PRR resistance within Australian chickpea varieties. The specific aim of this PhD project (BLG203) is to investigate the possibility to improve or select for PRR resistance based on variation in waterlogging tolerance; with short term benefits of understanding the interaction between PRR and waterlogging and improved sampling time for in-field molecular diagnostics.

Sources of PRR resistance in commercial chickpea varieties are scarce with the search for novel sources of resistance for incorporation into adapted northern region backgrounds continuing. Older varieties (Kyabra⊕, Jimbour, Moti⊕ and Yorker) vary with low to moderate levels of PRR resistance. More recent varieties (PBA HatTrick⊕& PBA Seamer⊕) are characterised by their moderate resistance to PRR, but have been shown across seasons to still suffer up to 20-70% yield loss from PRR. Wild chickpea has been found to have novel PRR resistance, however it is notoriously poorly adapted, having a prostrate growth habit with low yield and seed quality issues; making genetic lag a major challenge when breeding for PRR resistance. Extensive backcrossing into domestic chickpea material has been required to improve yield, seed quality and adaption whilst maintaining the high level of PRR resistance.

The following results discuss the response of two varieties and one breeding line; the domestic PRR susceptible variety Rupali, and moderately PRR resistant Yorker as well as the wild chickpea interspecific back cross genotype 04067-81-2-1-1 with high PRR resistance. Varieties PBA HatTrick⊕ and PBA Seamer⊕ commonly grown in the Northern region would perform similarly to Yorker with slightly less resistance; and Kyabra⊕ is similar to Rupali in terms of PRR resistance.

Disease symptoms and root characteristics of chickpea in response to waterlogging, PRR and both in combination

In a glasshouse experiment, foliar chlorosis was not observed in PRR resistant 04067-81-2-1-1 and moderately resistant Yorker seedlings in aerated PRR, waterlogging only or waterlogging + PRR treatments (Figure 2, left). However, under aerated PRR and waterlogging + PRR treatments the same entries suffered significant root disease symptoms including lateral root loss and primary root canker (Figure 2, right). The PRR susceptible entry Rupali had significantly increased chlorosis and root disease over 04067-81-2-1-1 and Yorker in both the aerated PRR and waterlogged + PRR treatments (Figure 2). The waterlogging treatment in the absence of PRR did not produce root necrosis or foliar chlorosis in any entry, being similar to the un-inoculated aerated control treatment (Figure 2).

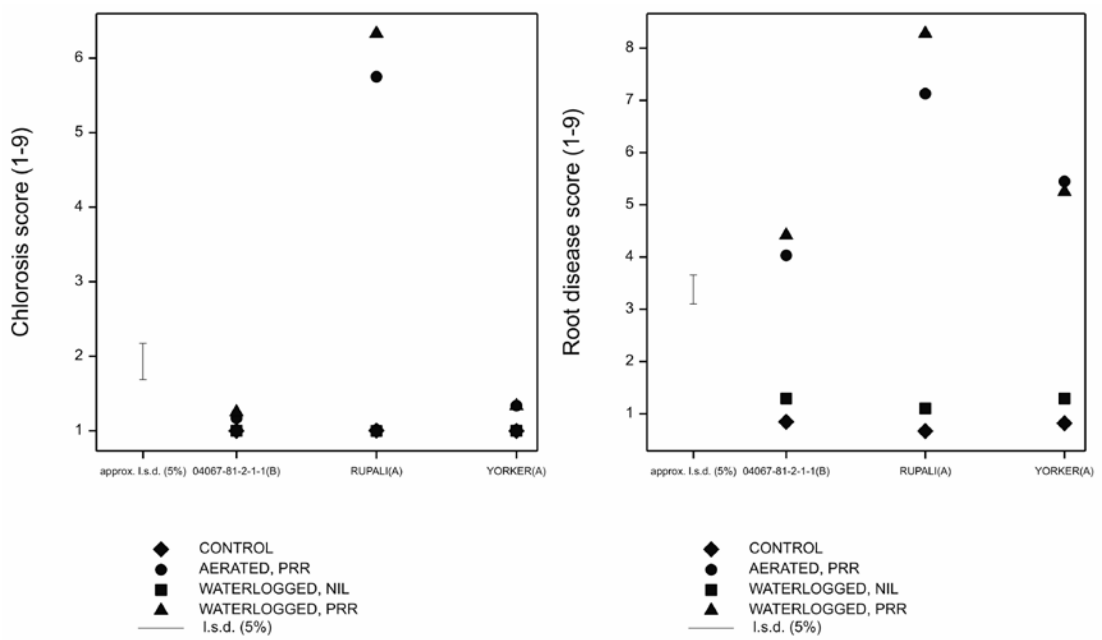

Figure 2. Foliar chlorosis (left) and root disease score (right) for chickpea entries under control conditions, aerated and PRR infected, waterlogged only and waterlogged with PRR infection. Chlorosis and root disease scale 1 =no symptoms, 9 = completely chlorotic foliage or total root loss. Root disease score rated the severity of necrosis in root tissue

04067-82-1-1 has been noted to have an inherently smaller root system compared to cultivated chickpea Yorker and Rupali; and had significantly reduced root volume when infected with PRR under both aerated and waterlogging treatments conditions (Figure 3, left). Yorker had no significant change in root volume across treatments compared with the control treatment, despite having a higher root disease score. Waterlogging alone did not significantly affect the root volume of 04067-82-1-1, Yorker and Rupali (Figure 3, left). Interestingly under the waterlogging only treatment Yorker trended towards having higher root volume than the control treatment. Whilst root length volume remains largely affected by genotype and PRR infection, primary root length was greatly influenced by both waterlogging and PRR treatments (Figure 3, right). Primary root growth appears to be halted in the presence of both PRR and waterlogging. The moderately PRR resistant Yorker and PRR susceptible Rupali however continued to suffer further root length reductions with the combination of waterlogging and PRR infection over the PRR resistant genotype 04067-81-2-1-1 (Figure 3, right).

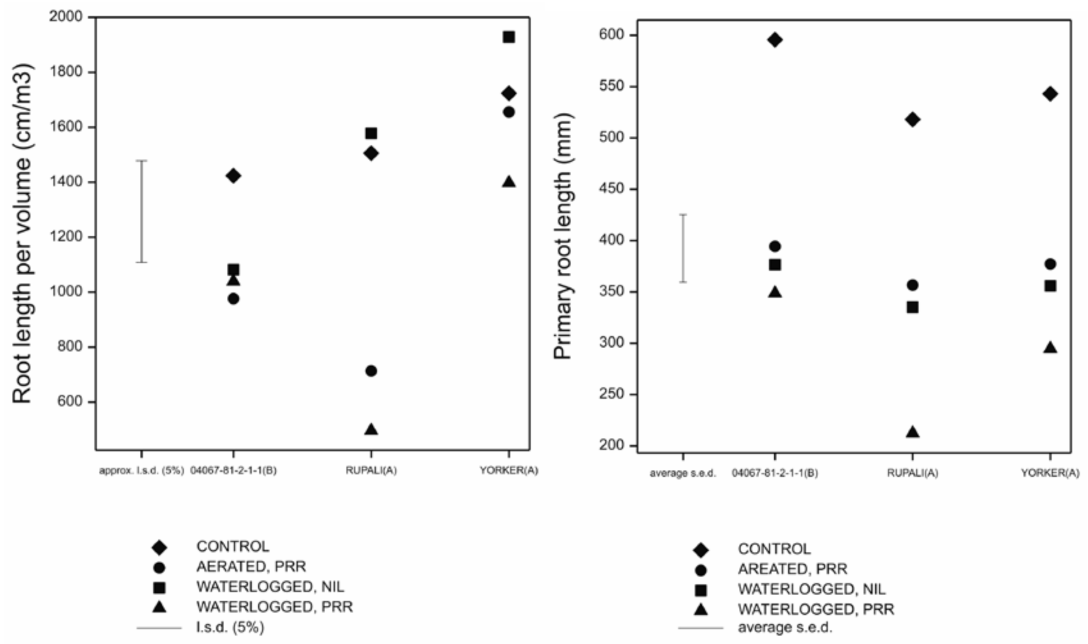

Figure 3. Root length volume (left) and primary root length (right) for chickpea entries under control conditions, aerated and infected with PRR, waterlogged only and waterlogged with PRR infection

What does it mean for growers?

Both waterlogging and PRR can cause advanced root lesions and/or reductions in growth prior to the appearance of chlorosis in leaf tissue, except when a PRR susceptible variety is infected with PRR. The environmental conditions, timing and duration of waterlogging will determine whether plant death or yield losses are attributed to PRR or waterlogging. When diagnosing visually it is important to dig up the roots soon after water receding to identify the presence of brown root lesions which indicate PRR infection. Waterlogged plants will not have initial root lesions and have lateral roots remaining which provide greater resistance when attempting to pull them from the soil compared to PRR infected plants.

Plants may survive waterlogging if it occurs early in the season and plant biomass is low enough for the reduced root volume to maintain plant metabolism. Following flooding, if chickpea plants survive, in the presence of *Phytophthora medicaginis* root lesions will appear after 8-10 days as Phytophthora germinates and infects upon the re-introduction of oxygen to the favourable moist environment. Potting mix and hydroponic experiments (data not shown) as anticipated, showed that under long term waterlogging (11 days) and a lack of oxygen, zoospores were greatly reduced or absent in solution and PREDICTA®B results demonstrated a reduction in the number of Phytophthora DNA copies detected compared to non-waterlogged treatments. These results indicate that when looking to diagnose PRR during a flood season, soil sampling 8 days after waterlogging with the inclusion of suspect chickpea root tissue may provide the best chance to identify the presence or absence of PRR using PREDICTA®B for paddock history purposes.

Losses from PRR infection in chickpeas are increased when they occur in combination with waterlogging; not necessarily because the pathogen is able to proliferate in the favourable conditions, but due to lack of oxygen during waterlogging when root growth is restricted. This limits the chickpea plants ability to compensate for root damage caused by PRR. Initial findings indicate that increased levels of resistance to PRR did reduce damage to chickpea roots under the combination of PRR and waterlogging. Root characteristics under waterlogging did change between the domestic and wild chickpea resistance sources. Understanding the impact of these root traits and usefulness for waterlogging tolerance and/or PRR resistance is ongoing, with a wider search to discover new sources of waterlogging tolerance and PRR resistance.

References

Bithell, S., Kelly, L., Hobson, K., Harden, S., Martin, W., Chiplin, G., & Moore, K. (2018). Phytophthora in chickpea varieties 2016 and 2017 trials –resistance and yield loss. *GRDC Updates paper*.

Van West, P., Appiah, A. A., & Gow, N. A. (2003). Advances in research on oomycete root pathogens. *Physiological and molecular plant pathology, 62*(2), 99-113.

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Nitrogen and water dynamics in farming systems – multi-year impact of crop sequences

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northern farming systems, nitrogen, fallow, water-use-efficiency, soil water

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Take home messages

- Grain legumes have utilised soil mineral nitrogen (N) to the same extent as cereal crops and have higher N export which often offsets N fixation inputs
- Additional applied N reduced the depletion of background soil mineral N status at most sites; we are recovering a high percentage (>50%) in soil mineral pool.
- Application of ~50 t/ha of compost or manure (10 t/ha OC) coupled with N fertiliser rates for 90th percentile yield potential has dramatically increased the soil mineral N in four years
- Decreasing cropping frequency has reduced N export and so stored more N over the longer fallows, which has reduced N fertiliser requirements for following crops
- Long fallows are mineralising N and moving N down the soil profile even under some very dry conditions
- Most excess N is not lost in the system rather it is moved down the soil profile for future crops
- The marginal WUE of crops (i.e. the grain yield increase per extra mm of available water) is lower when crops have less than 100 mm prior to planting. Hence, waiting until soil moisture reaches these levels is critical to maximise conversion of accumulated soil moisture into grain
- The previous crop influences the efficiency of fallow water accumulation with winter cereals > sorghum > pulses. Long fallows are also less efficient than shorter fallows (<8 months). This has implications for assuming how much soil moisture may have accumulated during fallows.

Introduction

While advances in agronomy and the performance of individual crops have helped grain growers to maintain their profitability, current farming systems are underperforming; with only 30% of the crop sequences in the northern grains region achieving 75% of their water limited yield potential. Hence, identifying ways to improve crop sequences to make more efficient use of soil water is needed. Growers also face challenges from declining soil fertility, increasing herbicide resistance, and increasing soil-borne pathogens in their farming systems. Change is needed to meet these challenges and to maintain farming system productivity and profitability. Consequently, Queensland

Department of Agriculture and Fisheries (DAF), New South Wales Department of Primary Industries (NSW DPI) and CSIRO are collaborating to conduct an extensive field-based farming systems research program, focused on developing farming systems to better use the available rainfall to increase productivity and profitability. Since 2015 experiments have been comparing farming systems and crop sequences designed to meet the emerging challenges. Experiments were established at seven locations; a large factorial experiment managed by CSIRO at Pampas near Toowoomba, and locally relevant systems being studied at six regional centres by DAF and the DPI NSW (Emerald, Billa Billa, Mungindi, Spring Ridge, Narrabri and Trangie (red & grey soils)). A common set of farming system strategies have been employed to examine how changes in the farming system impact on multiple aspects of the farming system.

Systems with best commercial practices (*Baseline*) at each location were compared to alternative systems with higher and/or lower crop intensity, higher crop diversity, higher legume frequency, higher nutrient supply and higher fertility (with the addition of organic matter).

Sites were selected to represent a range of climatic conditions, soil types, nutritional status and paddock history. Each site was comprehensively soil tested at the beginning of the project with ongoing soil sampling conducted prior to planting each crop and again after harvest.

Depths of testing:

- soil water; 0 – 10 – 30 – 60 – 90 – 120 – 150 cm
- nitrate and ammonium N; 0 – 10 – 30 – 60 – 90 cm
- comprehensive nutrient analysis; 0 – 10 – 30 – 60 – 90 - 120 – 150 cm

There is a considerable range in soil fertility across the sites which dramatically influenced the requirements for inputs of N fertilisers in particular at some sites (e.g. Billa Billa and Pampas) where high levels were present at the start of the experimental period.

This paper explores five years of data across all geographical locations to compare the nitrogen and soil water dynamics in different farming systems across the northern region, specifically:

- Changes in system nitrogen dynamics due to increasing legume frequency, increasing fertiliser inputs and decreasing crop frequency
- Where the nitrogen is in the soil profile and how it moves over long fallows and different fertiliser regimes
- Dynamics of soil water over different crop sequences demonstrating how these influence crop water extraction and accumulation during fallows
- How soil water availability influences crop water use efficiency and
- How crop type influences fallow efficiency.

How does increasing legume frequency impact on system N dynamics?

Grain legumes are integral in current farming systems. The area and frequency of legumes has consistently increased due to high grain prices and a belief that they improve soil fertility and reduce overall nitrogen (N) fertiliser input costs. The data produced from the Farming Systems project has allowed us to compare the effects of increasing legume frequency on N dynamics over a large geographic area. However, it is important to note here that as the project only has five years of data, all these systems have only planted 1 or 2 extra legume crops compared to the *Baseline*.

To date, results across our sites show that additional legume crops in the crop sequence has had little positive impact on soil mineral N except at Billa Billa (+ leg Figures 1, 2, 3 & 4). The legumes are actually utilising soil mineral N to the same extent as cereal crops and have higher N export which often offsets N fixation inputs. This result is consistent across various starting soil N conditions, from locations with very high starting mineral N status (e.g. Billa Billa - Figure 2 & Pampas – Figure 3) to locations with low mineral N status (Narrabri - Figure 4) where legumes would need to fix N to meet their needs. These results challenge the common assumption that grain legumes reduce N fertiliser needs in the crop sequence. Improved pulse breeding and agronomy has increased harvest index and hence the ratio of N removed in grain to that left in biomass, so residual N has been diminished after the crop.

What is the impact of increasing fertiliser inputs on system N dynamics?

With declining soil fertility across the northern region there is increasing interest in identifying ways to either halt or reverse the trend of increasing fertiliser inputs. Past research suggests that maximising biomass production is one way to achieve this. More biomass will increase soil organic matter levels which will build the natural supply of nutrients such as N and phosphorus. To maximise biomass production, supplying adequate crop nutrition is critical, along with providing nutrients to promote soil microbial processes.

The capacity to address nutrient depletion by increasing crop biomass and yield potential under favourable conditions was investigated, by implementing a system that increases nutrient supply budgets to target 90th percentile yield (*Higher nutrient*) compared to only 50th percentile yields in the *Baseline*. Another system was also implemented at two of the sites (Emerald and Billa Billa), *Higher fertility,* which also increases nutrient supply budgets to target 90th percentile yield but received an upfront addition of 10 t/ha organic carbon (as ~50 t/ha compost or manure) at the start of the experiment to raise the inherent fertility of the site. This system was designed to determine if a higher fertility level could be sustained with higher nutrient inputs.

The additional N that was applied in the *Higher nutrient* system (+ nut.) reduced the depletion of background soil mineral N status at eight of the ten sites (Emerald, Pampas mixed, Billa Billa & Narrabri shown Figures 1, 2, 3 & 4). The high starting nitrogen levels at Billa Billa has resulted in only one additional application of nitrogen in the *Higher nutrient* system for winter crop 2017, hence all systems have been utilising the original pool of N.

When comparing the *Higher fertility* system (+ fertility) at Emerald and Billa Billa (Figure 1 & 2) the additional organic carbon applied has dramatically increased the mineral N. The last two years has seen this system move ahead of all the systems at both sites. The largest change was seen at the Emerald site with this system holding an additional 150 kg available N/ha than the *Higher nutrition* system. It will be interesting to follow this system over further years to determine if this level of fertility can be maintained through the application of fertiliser rates budgeted for a 90th percentile yield potential.

These results show that applying N fertiliser to aim for a 90th percentile yield potential may reduce the mining of soil available N, and that significant amounts of additional N applied remains in the mineral N pool and hence is available in subsequent crops. To confirm this, longer term trends of underlying soil fertility such as organic carbon or total N pools will need to be assessed.

What is the impact of decreasing crop intensity on system N dynamics?

The Northern region farming system is centred on growing crops mainly on stored soil moisture. With low fallow efficiencies, the belief is often “use it or lose it”. However, others believe it is more profitable to increase fallow length to reduce the risk to individual crops by increasing soil water at planting. The nitrogen dynamics of this *Lower crop intensity* system (-inten.) are shown below at Pampas (Figure 3) and Narrabri (Figure 4). These systems are storing more N over the longer fallows, which is reducing N fertiliser requirements for following crops. Given the recent dry conditions and enforced long fallows it is interesting to consider the amount and location of available N for the next crop.

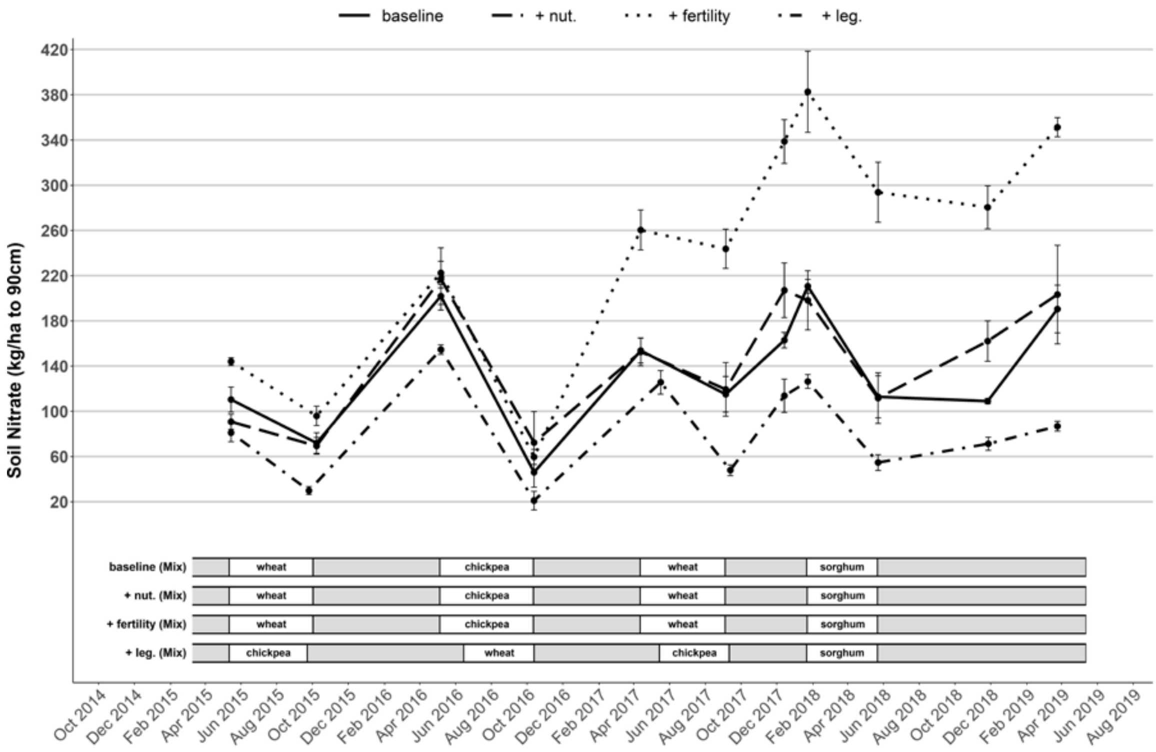

Figure 1. Dynamics of measured plant available soil nitrogen – Emerald

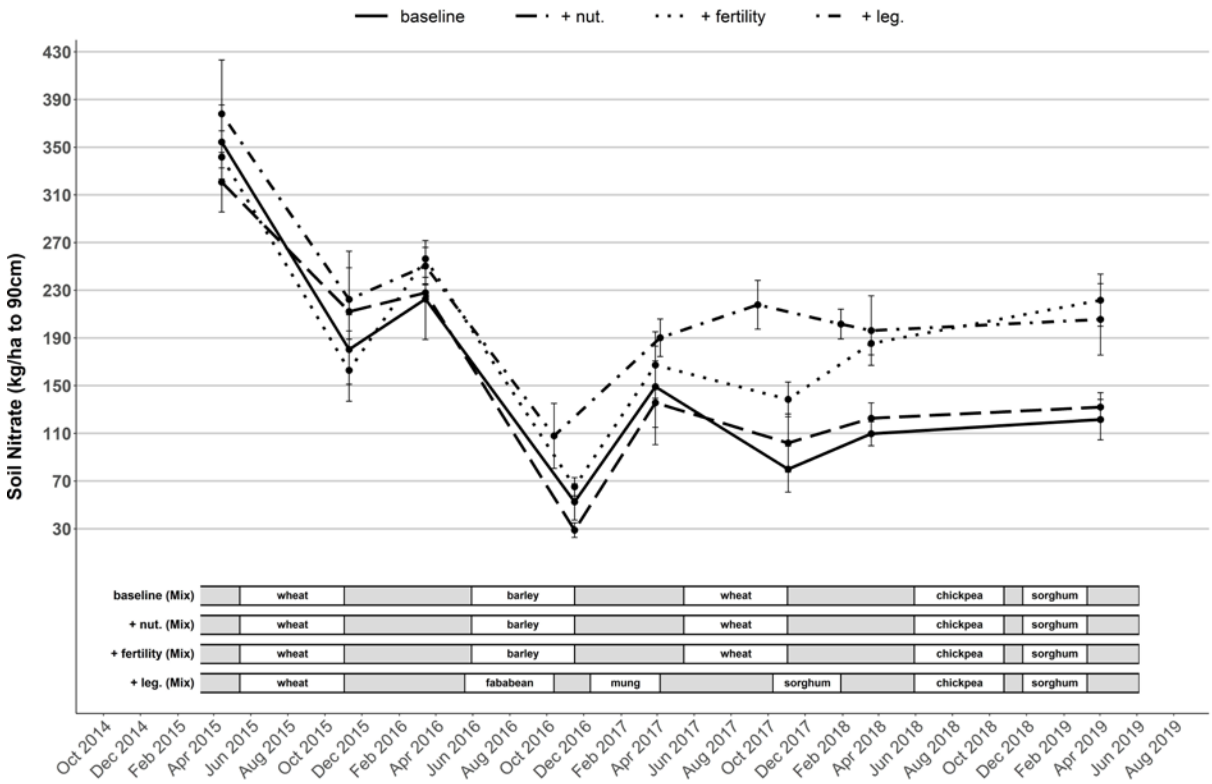

Figure 2. Dynamics of measured plant available soil nitrogen – Billa Billa

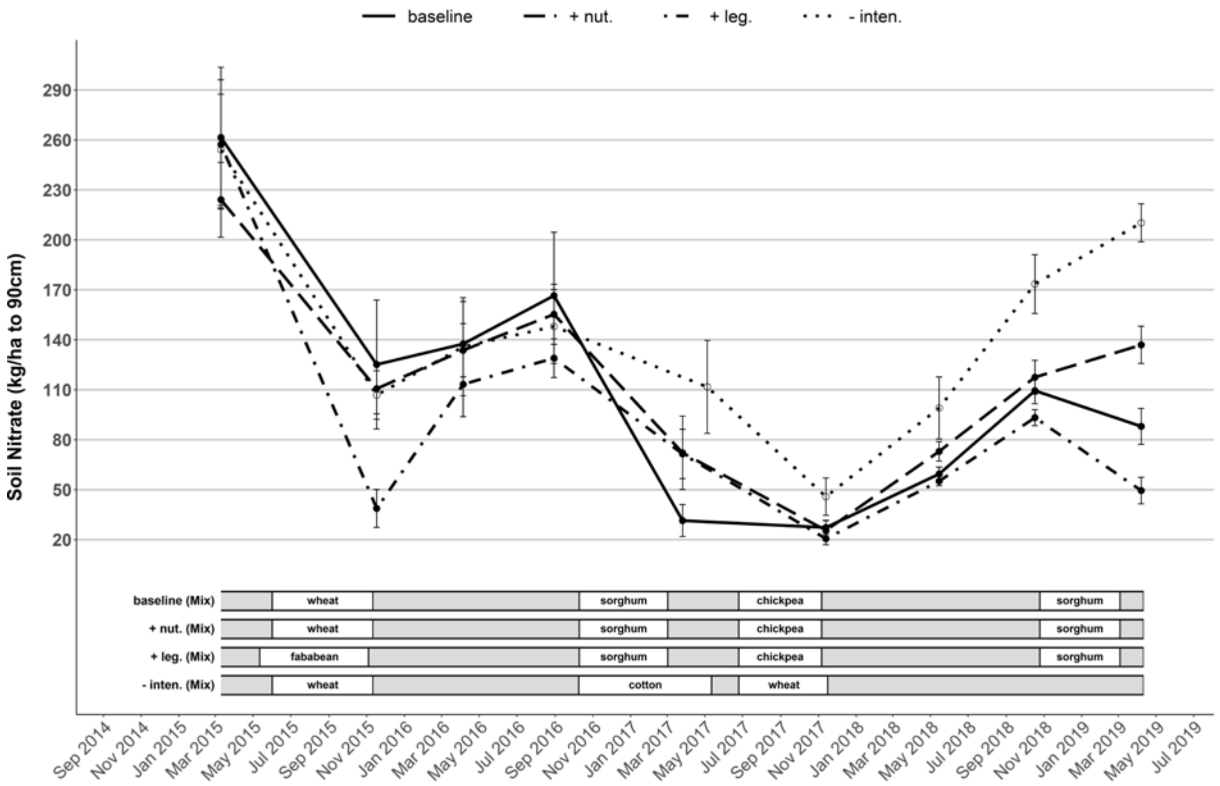

Figure 3. Dynamics of measured plant available soil nitrogen – Pampas mixed

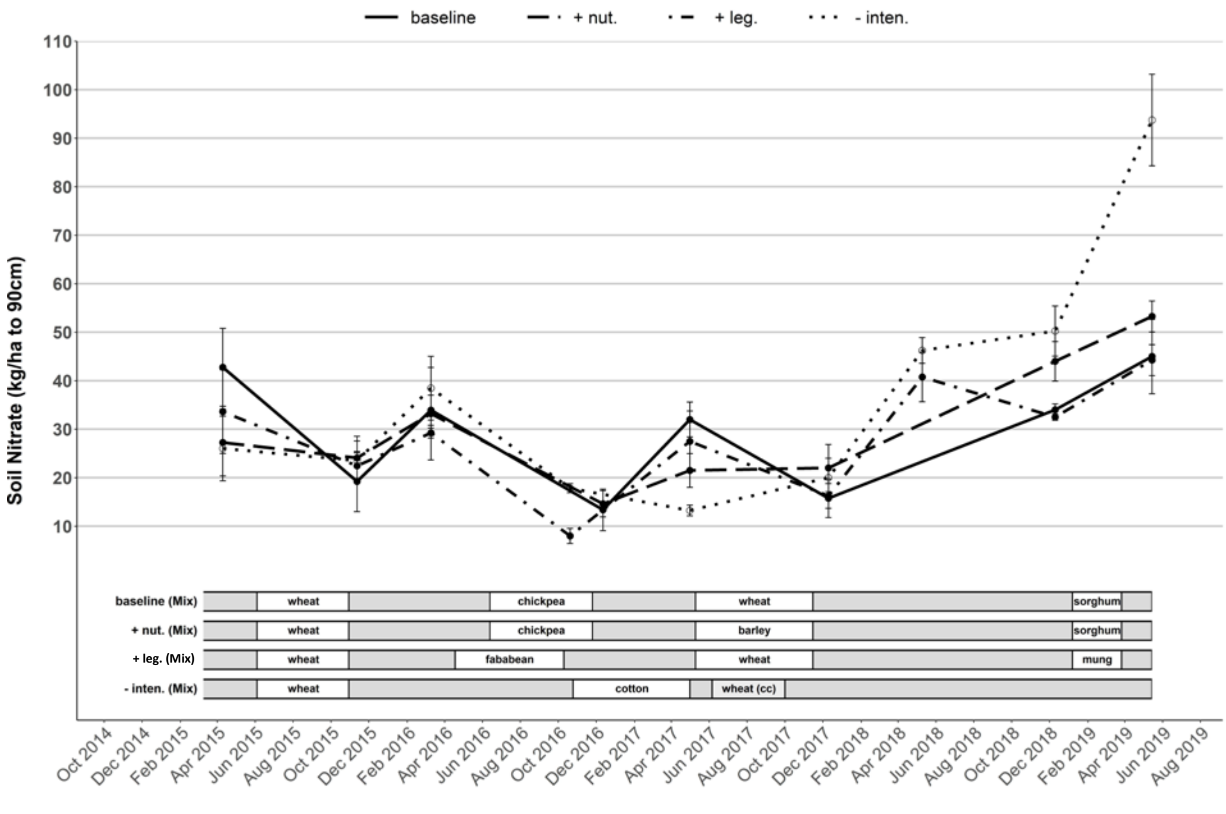

Figure 4. Dynamics of measured plant available soil nitrogen – Narrabri

Where is the nitrogen and how does it move in the soil profile?

When studying N dynamics over time the next question becomes 'where is the N and how does it move in the profile?' We have compared the starting available mineral N against that available after four years and where it is positioned in the soil profile at Emerald and Billa Billa (Figure 5). The Billa Billa site with its high starting fertility has seen N throughout the profile decline over time, with the largest change seen in the 0 – 10 cm. However, the Emerald site with its lower starting fertility and use of N fertiliser across all systems, has seen both the *Higher nutrient* and *Higher fertility* systems building N. The majority of this increase was in the 30 – 90 cm layers, indicating that excess N has moved down the profile during this time frame but is still available for future crops.

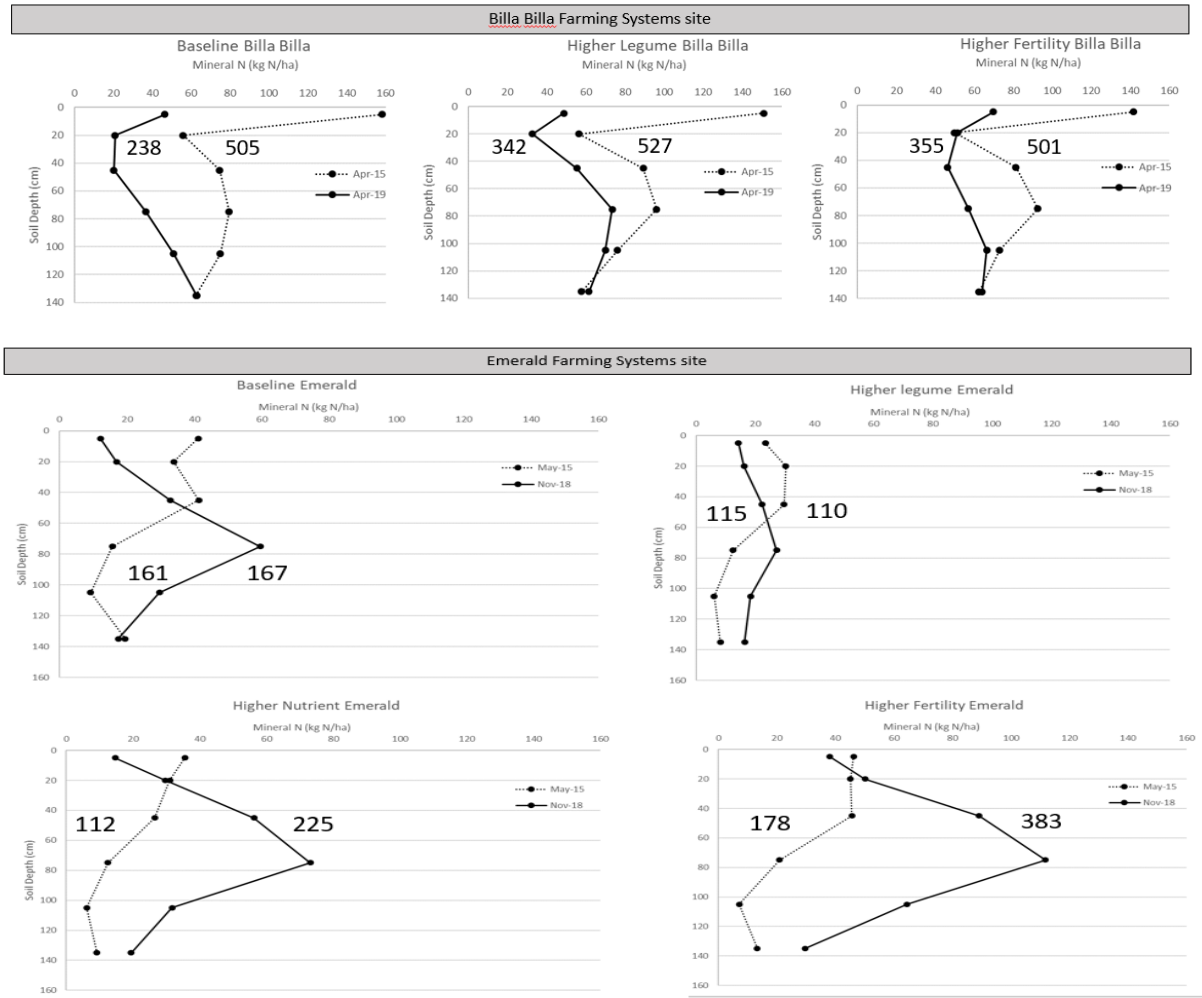

Figure 5. Distribution of mineral N placement within the soil profile from 2015 to 2019 at Billa Billa and Emerald

We know N mineralisation is related to soil type, organic carbon, biomass and rainfall – but what happens during extended dry periods such as the last 18 months across the northern grains region? After the initial increase of mineralised N in the topsoil across several sites, there was a definite movement of mineral N down through the soil profile. For instance, the summer season of 2017/18 saw significant levels of mineralisation within the 0 - 30 cm depth at the northern farming systems sites (Figure 6 - Narrabri and Pampas). This summer recorded below average rainfalls, but there was obviously still sufficient rain to trigger mineralisation. The increase in the 0 – 30 cm corresponds with the location of microbes responsible for the breakdown of organic matter into the plant available form of nitrate and ammonium. Sampling after the winter of 2018 found that the N mineralised during the previous summer, had filtered down the profile into the lower depths (30 - 60 cm). This pattern continued late into the fallow as the accumulated mineral N increased in the 60 - 90 cm depth. These results show that mineralisation can be triggered by even small falls of rain and this N can then move down the soil profile even with lower soil profile moisture levels or when rain does fall. This is important for the next phase of the cropping sequence, as it can be assumed that not only do we have ample mineral N available to maximise grain yields, but the location of the N is within the soil layers where plants require peak N uptake during key growth stages.

The Mungindi site (Figure 7) had preplant N applied for a winter crop that was not planted (2017). The *Baseline* received 20 kg N/ha and the *Higher nutrient* system received 80 kg N/ha in April 2017. The following year soil analysis showed that large amounts of N had mineralised and that this mineralised N and fertiliser N moved into the 10 - 30 and 30 - 60 cm layers during a very dry year. This data shows that if N is applied and not utilised by a crop that it may not be lost from the system but rather move down the profile to support future crop growth and grain production.

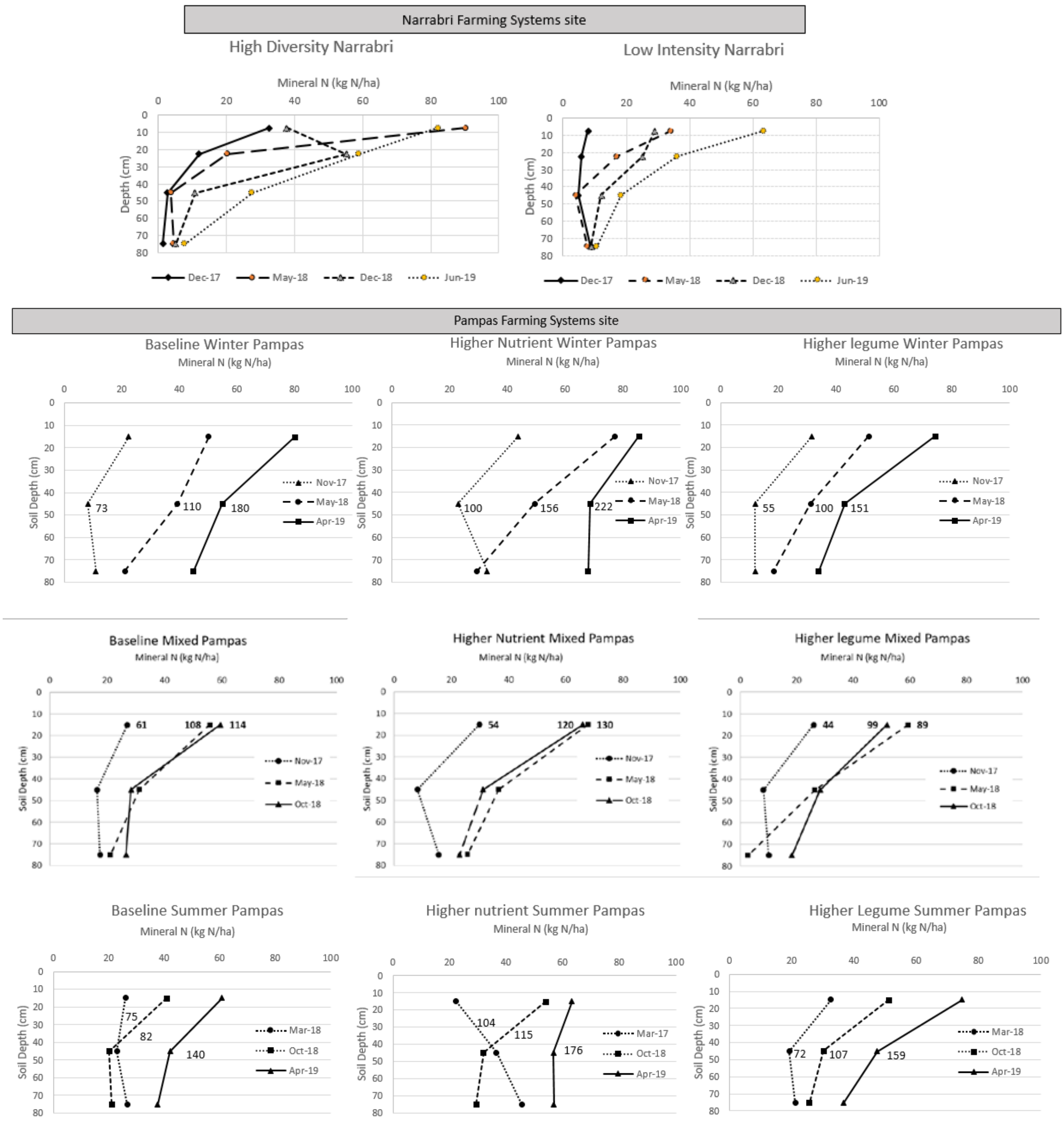

Figure 6. Distribution of mineral N placement within the soil profile over a long fallow period at Narrabri and Pampas

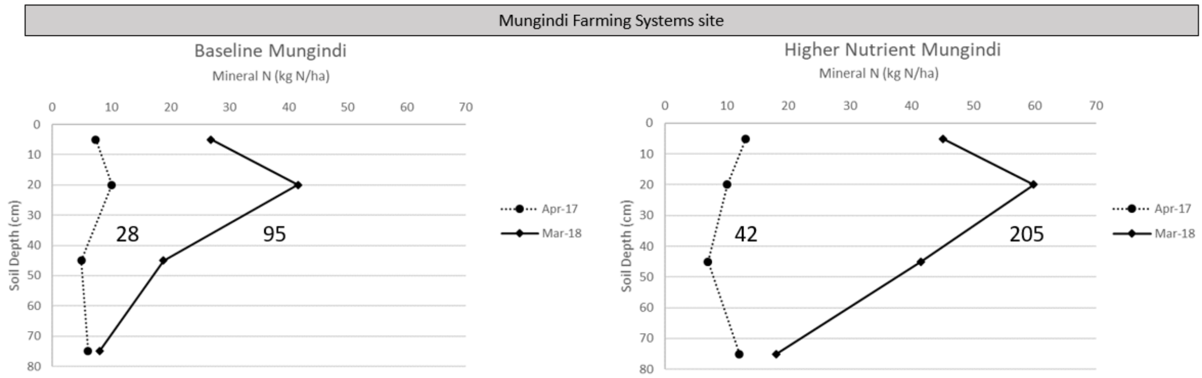

Figure 7. Distribution of mineral N placement within the soil profile over a long fallow period at Mungindi

Untangling the water use efficiency of crop sequences

System water use efficiency of a crop sequence is driven by the efficiency of its fallows (i.e. the proportion of rain falling during the fallow that accumulates in the soil to be available for the next crop) and how efficiently the subsequent crops can convert both the accumulated soil water and in-crop rainfall into grain or product. We have monitored crop water use, water use efficiency and subsequent fallow water accumulation for over 300 different crops to explore how soil water accumulates and is used over different crop sequences.

How does cropping intensity impact on plant available water (PAW) dynamics?

Cropping intensity impacted on the depth of recharge of the soil profile. In the two examples below at Billa Billa (Figure 8) and Pampas (Figure 9) the higher intensity soil profile was never allowed to refill as fully as the *Lower intensity* and *Baseline* systems. While there are implications on yield and WUE (discussed later in this paper) for having less stored water, not allowing the profile to fill may also affect the plants' ability to extract deep nutrients.

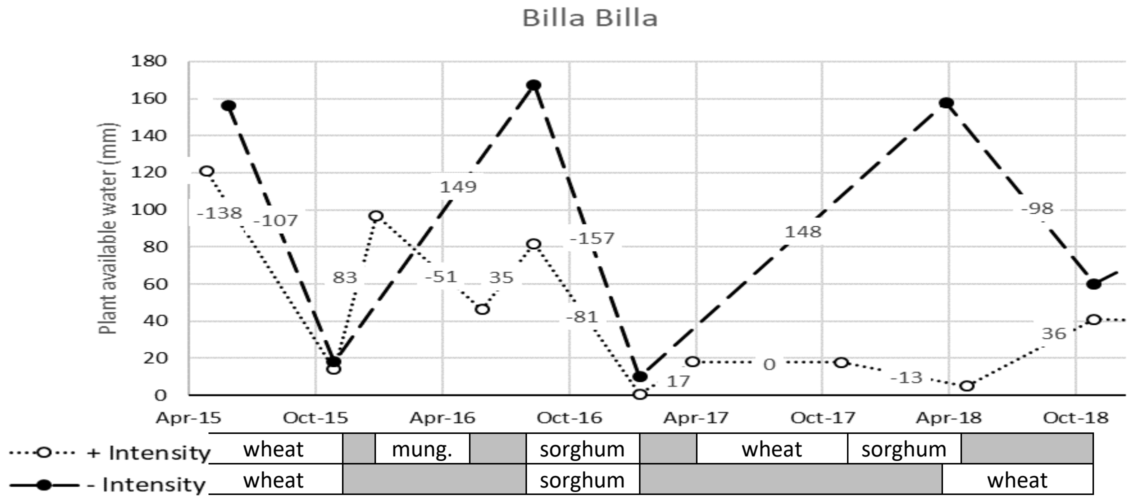

Figure 8. Plant available water (PAW) dynamics of two of the Billa Billa cropping systems. *Nb. Plots were often soil sampled up to 6 weeks prior to planting; crop duration indicated in the chart is from pre-plant soil sample to post-harvest soil sample (not plant to harvest). Numbers show the net change between the two soil water readings

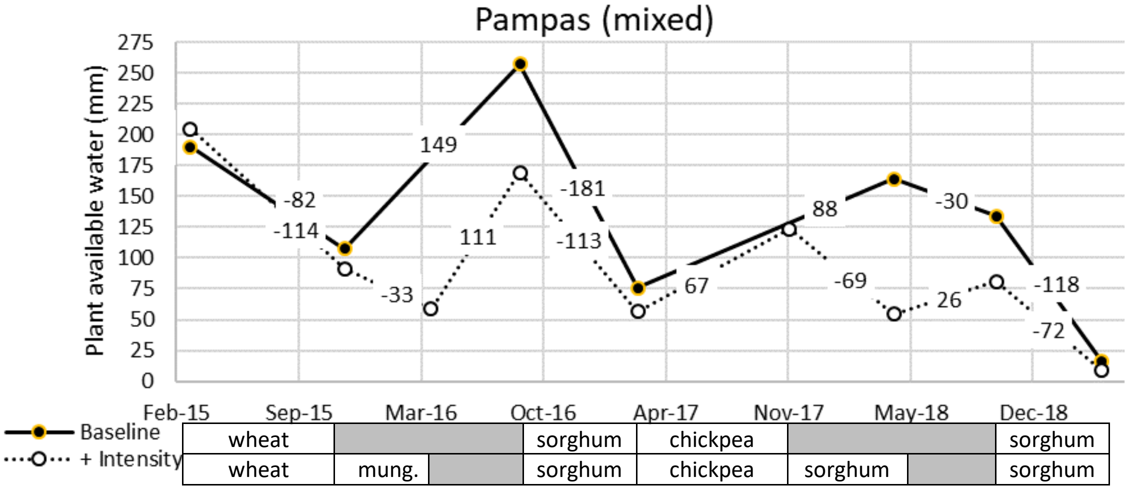

Figure 9. PAW dynamics of two of the Pampas mixed summer/winter cropping systems. *Nb. Plots were often soil sampled up to 6 weeks prior to planting; crop duration indicated in the chart is from pre-plant soil sample to post-harvest soil sample (not plant to harvest). Numbers show the net change between the two soil water readings

How does crop choice impact on PAW dynamics?

The Billa Billa Belah duplex soil is constrained by sodicity at depth, so pulse crops have left water below 50 cm. This deep PAW and rainfall at opportune times has allowed double cropping after pulses – an option that was not available in the systems where cereal crops (or canola) were grown (Figure 10) due to their higher ability than pulse crops to extract water from sodium constrained zones. This has allowed the *Higher legume* system to increase its cropping intensity, with the same PAW planting triggers as the *Baseline*. Similarly at Billa Billa, the *Lower intensity* wheat grown in 2018 reduced the profile by 98 mm (Figure 8) while chickpeas in the *Baseline* and *Higher legume* systems only reduced the profile by 39 and 34 mm respectively (Figure 10), allowing them to double crop to sorghum on the next rainfall event.

On the 'less constrained' black Vertosol at Pampas, the difference in PAW extraction is much less stark. There is still a difference in crop lower limits between the pulse and cereal crops, however the difference is much less. For example, faba beans and wheat were planted in the same season, with similar starting PAW (Figure 11). At harvest the wheat had extracted 14 mm more than the faba bean (compared to 53 mm in the constrained site). After harvest the wheat accumulated an extra 14 mm PAW, so that the two systems had the same PAW again when a winter crop was planted in the winter only systems. However, in the mixed systems the fallow was continued to sorghum in October 2016. With the longer fallow, the wheat stubble continued to provide higher fallow efficiency so had 12 mm more PAW at planting than the faba bean stubble. The extra stored PAW was used by the following sorghum crop, so that the two systems had the same PAW post-harvest and have maintained the same rotation and similar PAW since (Figure 11).

At Mungindi the *Baseline* and *Lower intensity* systems had the 2015 wheat crop in common. However, in 2016 the *Baseline* was planted to chickpea, while the *Lower intensity* was fallowed to cotton in the spring (Figure 12). A large portion of the rain that fell in that season was in the spring, when the chickpea and cotton crops were both in the ground, but with very little rainfall from chickpea harvest to cotton harvest. The cotton crop left the soil 32 mm drier than the chickpea at their respective harvests (chickpea was 19 mm drier at cotton picking), but a combination of residual wheat stubble and dry cracked soil post-cotton, resulted in the lower intensity system having an extra 15 mm PAW when the two systems were planted to wheat in 2018.

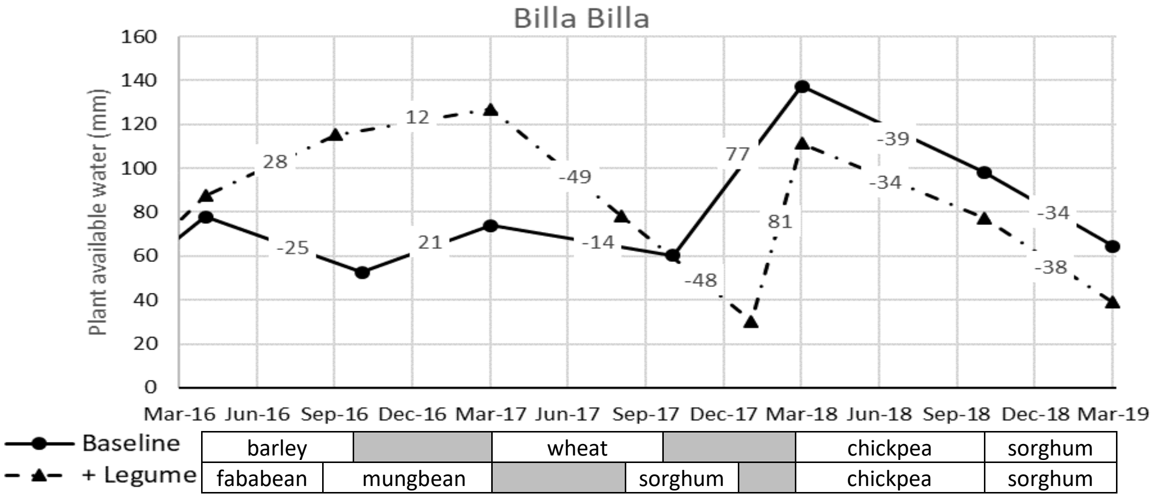

Figure 10. PAW dynamics of two of the Billa Billa cropping systems. *Nb. Plots were often soil sampled up to 6 weeks prior to planting; crop duration indicated in the chart is from pre-plant soil sample to post-harvest soil sample (not plant to harvest). Numbers show the net change between the two soil water readings

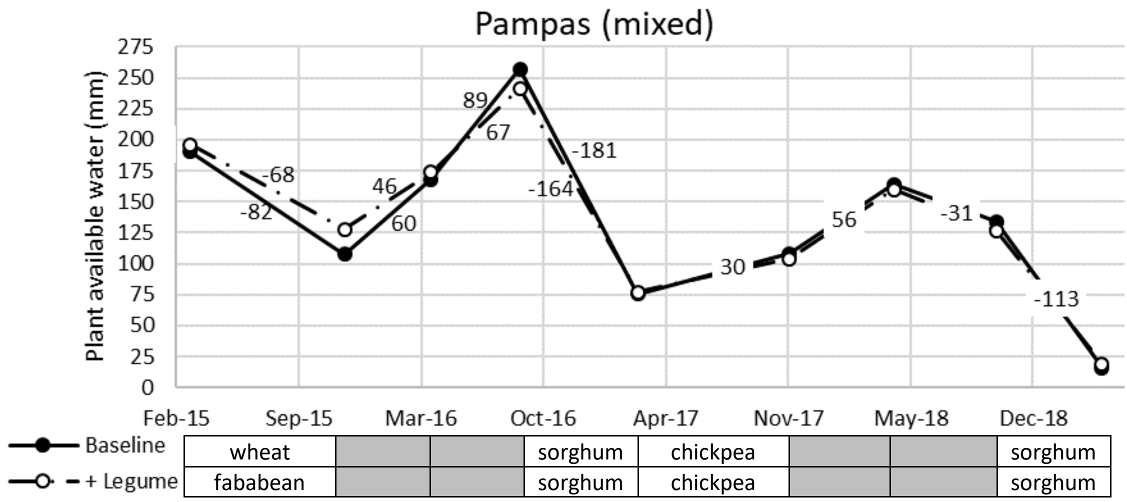

Figure 11. PAW dynamics of two of the Pampas mixed summer/winter cropping systems. *Nb. Plots were often soil sampled up to 6 weeks prior to planting; crop duration indicated in the chart is from pre-plant soil sample to post-harvest soil sample (not plant to harvest). Numbers show the net change between the two soil water readings

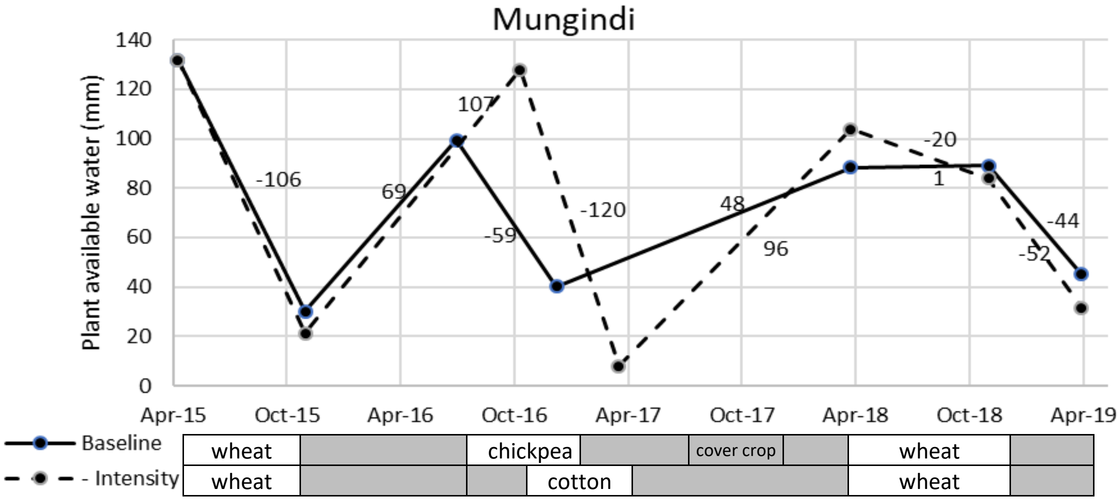

Figure 12. PAW dynamics of two of the Mungindi cropping systems. Numbers show the net change between the two soil water readings

Drivers of crop water use efficiency

The availability of water is a key driver of crop yields in Australian farming systems and hence understanding what drives crop water use efficiency (WUE; the kg of grain produced per mm of crop water use) is critical. A relationship between grain yield and crop water use has been widely used to demonstrate the WUE potential of crops across different environments. In northern farming systems the water available to the crop can come from stored soil water at planting and in-crop rain; In contrast to southern Australia where in-crop rain alone has often been used to calculate crop WUE. Further, the unreliability of in-crop rain can mean that the stored moisture can make up a large proportion of the water available to the crop, and hence has high importance for determining crop yield and crop WUE.

Using the data collected from the farming systems experiments we show that the marginal WUE (kg/mm of additional crop water use) reached its potential at 24 for wheat, 12.5 for chickpea and 18 for grain sorghum. Despite this potential and optimal crop management in these experiments, in most cases the average across all the crops measured was lower; 15.3 for wheat, 8.8 for chickpea and 14.3 for sorghum (Figure 13, TOP). This demonstrates that while WUE is a useful benchmark, there is large season to season variability due to the timing of rainfall events or other stresses that may reduce crop yields.

There is no clear relationship between planting soil water and crop yield across this data, due to large seasonal differences in in-crop rain. Nonetheless, we found some interesting relationships between available soil water at planting for the crop and the marginal WUE that that crop achieved (Figure 13, MIDDLE). This shows that in general, the WUE of crops increases as more soil water is available at planting. Crops of wheat, chickpea and sorghum that had less than 100 mm of plant available water coming into the season, had much less chance of achieving high crop WUE. This is because crops planted on marginal soil moisture are more at risk of depleting the soil profile prior to flowering and the critical grain filling period, unless significant in-crop rainfall occurs. This data suggests that chickpea may be less susceptible than wheat or sorghum to this. We could hypothesize that this is because chickpea has a lower water requirement prior to the start of grain filling and the indeterminate growth habit means that acute water stress at critical phenological times impact less severely on grain yield.

Finally, the gap between the marginal WUE of each crop compared to the potential predicted here (dashed lines) increases significantly in crops with lower soil water prior to planting. Figure 13 (BOTTOM) shows the rate that crop WUE declines per mm of available water across a range of starting soil water conditions. This indicates that the lower the soil water is at planting, the more quickly that WUE will decline. This further demonstrates that crops planted on lower soil water are likely to achieve suboptimal crop WUE and this relationship is not linear. That is, as less soil water is available, the likely reduction in WUE increases further.

In summary, this analysis shows that soil water prior to planting is a critical driver of how efficiently a crop converts the water available to it into grain. It is worth noting however, that this analysis was done using soil water samples prior to planting and hence, in some cases did not include the planting rainfall event itself. Hence, if another 15-20 mm is required to achieve this then this was not included these calculations of soil water at planting.

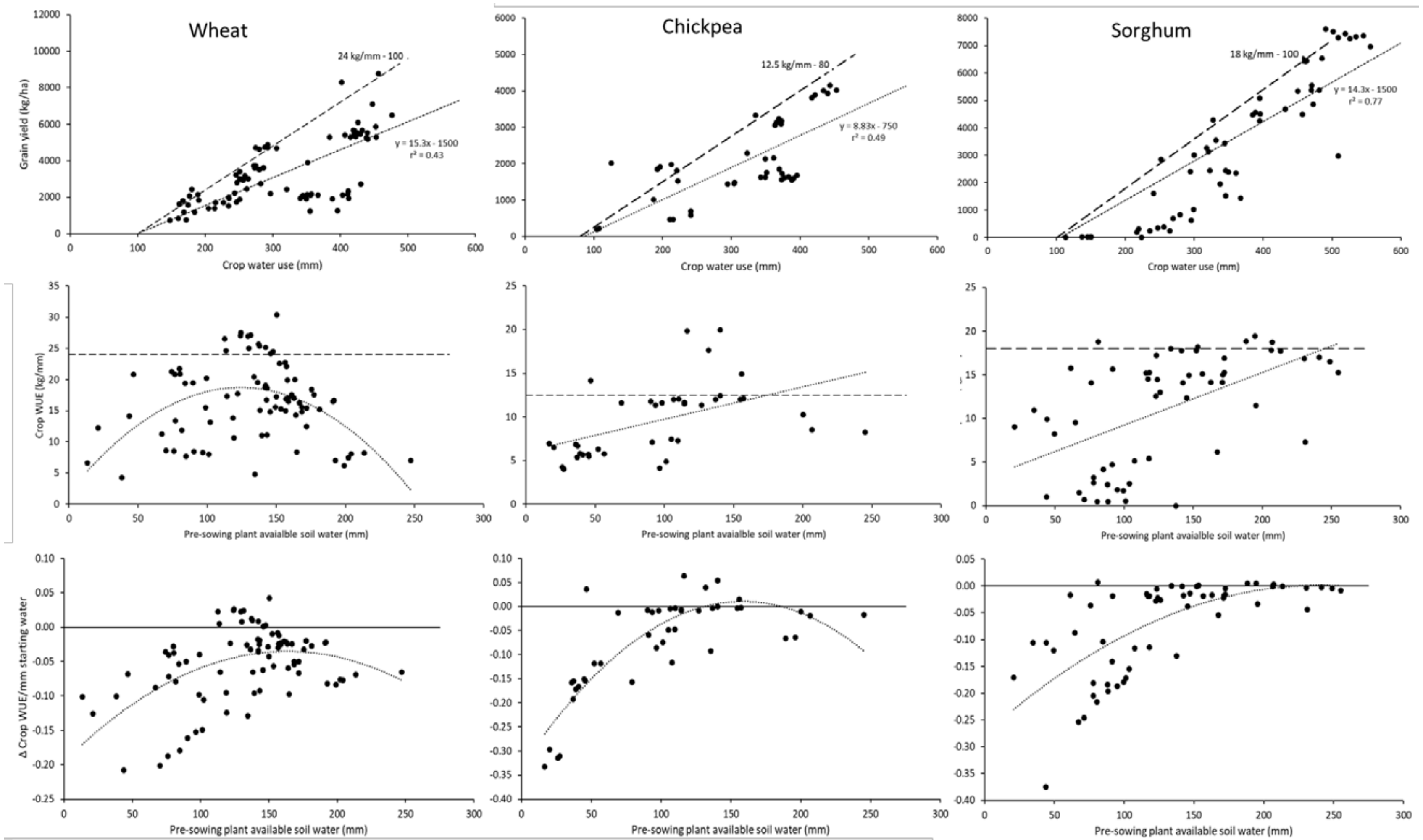

Figure 13. Relationships between water availability and crop yield and water use efficiency (WUE) in wheat, chickpea and grain sorghum collated from data collected across farming systems research sites. TOP –Crop water use (change in soil water plus rainfall) *vs.* grain yield, showing the maximum potential (dashed line) and the average across the dataset (dotted line); MIDDLE – Plant available soil water prior to planting *vs.* crop WUE (as calculated above); and BOTTOM – Plant-available soil water prior to planting vs the difference between the measured crop WUE and the potential WUE per mm of additional water available (dashed lines in above figures)

Crop effects on efficiency of subsequent fallows

Here we have collated this data to compare how different crop types impact on subsequent fallow efficiencies (Table 1). We have removed fallows with little rain (<80 mm) because this distorts the values of FE.

Based on > 20 different fallows we monitored, this quantifies some clear crop effects on subsequent fallow efficiencies – typically related to the ground cover provided and its persistence. Winter cereal crops provide the highest fallow efficiencies while the lower cover after winter pulses results in lower fallow efficiencies. Sorghum is intermediate. With fewer observations, fallow efficiencies after canola were intermediate between the winter pulses and winter cereals. Cotton produced much lower fallow efficiencies. The data also clearly shows that short-fallows are more efficient than longer fallows, because during long-fallows the soil is wetter for longer and hence there is more evaporative losses and residue cover levels are reducing with time.

Table 1. Comparison of efficiencies of fallow water accumulation (i.e. change in soil water/fallow rainfall) following different crops. Data are an average of fallows monitored across the farming systems experiments in northern NSW and southern Qld between 2015 and 2019. Only fallows receiving more than 80 mm of rain are included.

Previous crop	**All fallows**	***n.***	**Short fallow (<8 months)**	***n.***	**Long fallows (> 8 months)**	***n.***
Winter cereals (wheat, durum, barley)	30%	*81*	34%	*54*	21%	*27*
Winter pulses (chickpea, fababean, field pea)	20%	*36*	25%	*20*	15%	*16*
Sorghum	22%	*23*	28%	*7*	19%	*16*
Canola	26%	*5*	31%	*4*	6%	*1*
Cotton	16%	*3*			16%	*3*

This means that the impacts of a particular crop on the accumulation of soil water in the following fallow should be considered in the cropping sequence. For example, a fallow receiving 400 mm of rain after a winter cereal would accumulate 120 mm on average, while the same fallow after a grain legume would have only accumulated 80 mm. This difference could have a significant impact on the opportunity to plant a crop and/or the yield and gross margin of the following crop in the cropping sequence.

Conclusions

Nitrogen

Improved pulse varieties and agronomy has seen greater use of pulses. This has not provided increased nitrogen benefits to following crops as the pulse crops often mine mineral nitrogen from the profile. However, increasing nitrogen budgets to 90th percentile yield potential at planting has meant crops have left nitrogen behind in most seasons, so the nitrogen can move down the profile and accumulate in the deeper soil layers. This effect is accentuated where we also added organic carbon to the system, as the soil is suppling more nitrogen to the mineral pool.

Increasing the time spent in fallow is also allowing the soil to mineralise more N, and the small rainfall events in the recent dry seasons have been sufficient to move N down the profile.

Regardless of the source, excess nitrogen was rarely lost to the system, rather it was moved down the soil profile for future crops, and presumably some has moved into the organic pool. But the only way to be sure how much and where nitrogen is positioned is with a well segmented soil test.

Water

In a northern farming system, grain yield is highly dependent on how much water is stored in the profile during the preceding fallow. The efficiency of capturing and storing fallow rainfall is driven by the stubble left by the previous crops and the duration of the fallow period. Crop type also influences how efficiently crop water use is converted to grain. This research suggests storing more than 100 mm PAW prior to planting increases the likelihood of optimising crop WUE.

Increasing cropping intensity by planting with less stored moisture, reduces the potential to recharge deep soils, which can limit the plants ability to access deep stored nutrients.

Crop choice can dictate the next planting opportunity through the different residual water levels at harvest and fallow efficiency of the stubble left behind. This opportunity could be quite different in the presence versus absence of soil constraints.

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Farming system profitability and impacts of commodity price risk

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Take home messages

- Large gaps in profitability are possible between the best and worst systems – differences of $92-494/ha per year were found between systems at each site
- Intensity is the major factor driving good/poor economic performance of the farming system - more so than crop choice. Matching intensity to environmental potential seems to be the most important lever to optimise farming system profitability
- Increasing crop intensity increased costs and risks, but potentially higher crop income wasn't realised over the dry run of seasons and hence has produced lower gross margins than more conservative systems
- Lower crop intensity had lower system gross returns, but because of lower inputs and costs may achieve a more favourable return on investment at lower risk when there are limited planting opportunities. These systems have achieved lower gross margins than the baseline system in all but one comparison
- Increasing legume frequency has the potential to capitalise on favourable legume prices but using long-term prices has rarely exceeded gross margins of baseline systems
- Increasing nutrient supply incurred higher costs and required favourable seasonal conditions to increase grain yields and gross margins – this rarely occurred over the experimental years (excluding Trangie 2016 and Emerald 2017 where significant crop responses were obtained)
- Systems involving crops with higher price variability (e.g. pulses, cotton) had limited downside risk but increased upside opportunities of higher economic returns. Even when comparing recent and long-term grain prices, the relative profitability ranking of systems rarely changed
- Selecting a crop system is a long-term decision with unknown future yield and prices, hence choose systems that maximise system productivity and resilience, rather than responding to current commodity prices.

Introduction

Leading farmers in the Australian northern grains region (NGR) perform well in terms of achieving the yield potential of individual crops. However, the performance of the overall system is harder to measure and less frequently well considered. The key factors appear to relate to issues occurring across the crop sequence such as poor weed management, disease and pest losses, sub-optimal fallow management and cropping frequency. Similarly, farming systems are threatened by the emerging challenges of increasing herbicide resistance, declining soil fertility and increasing soil-borne pathogens, all of which require responses to maintain total system productivity. Questions are emerging about how systems should evolve to integrate practices that:

- Efficiently capture and utilise rainfall particularly for high-value, low-stubble crops
- Reduce costs of production and the likelihood of climate-induced risk
- Respond to declining chemical, physical and biological fertility
- Improve crop nutrition and synchrony of nutrient supply
- Suppress or manage crop pathogen populations
- Reduce weed populations and slow the onset, prevalence and impact of herbicide resistance
- The price risk of individual crops and the impact on systems' economic returns.

Because of the multi-faceted nature of these challenges, an important need is for a farming systems research approach that develops an understanding of how various practices or interventions come together. This requires quantifying synergies or trade-offs and investigate the impact on whole-of-system productivity, risk, economic performance and sustainability.

As a result, research was initiated in 2014 to identify the key limitations, consequences and economic drivers of farming systems in the NGR. The aim is to assess the impacts of modifying farming system on multiple attributes (e.g. nutrients, water, pathogens, soil health, and economics) across multiple sites. Experiments were established at seven locations and a large factorial experiment at Pampas near Toowoomba with locally relevant systems being studied at six regional centres across central and southern Qld (Emerald, Billa Billa, Mungindi) and northern NSW (Spring Ridge, Narrabri and Trangie).

Assessing how changes to the farming systems alter profitability is critical. This paper examines the economic performance of different modifications that we have tested in combination with commodity price risk. This will help quantify the costs or benefits of changing the farming system and the trade-offs for the different cropping intensities and nutrient strategies.

System modifications being tested

We used a set of farming system strategies across our site locations within the NGR. These strategies resulted in different cropping systems per location, based on the environmental (climate & soil) conditions. Below we outline the common set of farming system strategies employed across the farming systems experimental sites over the past 4.5 years.

- **Baseline** – an approximation of current best management practice in each district against which each of the system modifications are compared: involves only dominant crops used in the district; sowing crops on a moderate soil water threshold (i.e. 50-60% full profile) to approximate moderately conservative crop intensities (often 0.75-1 crop per year); and fertilising to median crop yield potential
- **High crop intensity** – aims to increase the proportion of rainfall transpired and reduce unproductive loses by increasing the proportion of time that crops are growing; this is implemented by reducing the soil water threshold required to trigger a planting opportunity (e.g. 30% full profile) so that cropping intensity is increased relative to the baseline
- **Low crop intensity systems** – this aims to minimise risk by only growing crops when plant available soil water approaches full (i.e. > 80% full) before a crop is sown and higher value crops are used when possible. This requires longer fallows and will lower crop intensity relative to the baseline

- **High legume frequency** – crop choice is dictated to have every second crop as a legume across the crop sequence and uses high biomass legumes (e.g. fababean) when possible.
- **High crop diversity** – a greater set of crops are used with the aim of managing soil-borne pathogens and weed herbicide resistance risk through crop rotations. This implemented by growing 50% of crops resistant to root lesion nematodes (preferably 2 in a row) and 2 alternative crops are required before the same crop is grown in the crop sequence
- **High nutrient supply -** increasing the fertiliser budget for each crop based on 90% of yield potential rather than the baseline of 50% of yield potential.

At several sites there are also some additional, locally relevant systems implemented. These include:

- **Higher fertility systems** (Billa Billa and Emerald) where the high nutrient supply system is also complimented with the additions of a large amount of organic amendments with the aim of boosting background soil fertility. The aim is to see if this can be maintained when used in combination with the higher nutrient input strategy, as well as the economic outcome.
- **Integrated weed management systems** (Emerald). The system has implemented combinations of agronomic management options particularly focussed on summer grass weeds (e.g. feather-top Rhodes grass) such as higher levels of crop competition and use of multiple herbicide modes of action.
- Two **low-intensity systems** have been implemented at Mungindi, one involving only grain crops and the other implementing cotton in the rotation when conditions are appropriate.

Finally, at the core experimental site at Pampas, each of these system modifications are being tested in a factorial where some modifications are combined, with the four overarching themes being: mixed opportunity, intensive, summer-cropping, and winter-cropping dominant.

Quantifying system profitability and commodity price risk

Over the 4.5 experimental years we have collected data on crop grain yields, the total inputs of machinery operations, fertilisers, seed, herbicides and other pesticides for each cropping sequence. This allows us to calculate the accumulated income (sum of grain yield x price for all crops in the sequence) and total gross margins (income minus costs) for each of the cropping systems deployed at each location (Table 2 and Table 3). Prices for inputs of fertilisers, herbicides, other pesticides and seed were based on market prices at purchase for each input. Costs for operations differed by crop to reflect different contract rates or machinery requirements, but fertiliser applications ($8/ha) and each spraying operation ($3/ha) were held constant. All grain yields were corrected to 12% moisture irrespective of harvest moisture levels. We have used consistent prices for each commodity and inputs across all locations to avoid introducing discrepancies in the data.

In this research we used the key metric of "total gross margins" to compare system profitability per hectare across environments and cropping systems over the whole period (4.5 years). It should be noted that gross margins do not include overhead, or other fixed costs associated with the farming enterprise, as these are likely to vary significantly from farm to farm and region to region.

Initially we have calculated these system gross margins using 10-year median commodity price over the period 2008-2017 (adjusted for inflation, transportation, grading or bagging costs) (Table 1). However, to explore the impact that variability in commodity prices may play on the relative profitability of different crop sequences we have then calculated the gross margin across a full set of combinations of prices for each crop commodity that may have been received over the past 10 years. We also calculate the specific gross margin for each crop system using commodity prices received over the last 3 years (see Table 1) to see the actual economic outcome during the experimental period and where they fell within the range of possible outcomes.

Table 1. Market commodity prices and farm gate prices used for calculating system gross margins for each crop grown across the farming systems experiments.

		Barley	Wheat (APH)	Wheat (Durum)	Canola	Chickpea	Fababean	Fieldpea	Sorghum	Maize	Mungbean	Sunflower	Cotton (Lint + seed – 40% turnout)*
Port Prices ($/t)	10-yr median	258	309	339	543	544	422	375	261	321	950	749	1267
	3-yr average	254	287	317	518	831	419	364	255	325	1151	905	1243
Transportation costs ($/t)		40	40	40	40	40	40	40	40	40	40	40	40
Grading and bagging costs ($/t)		0	0	0	0	0	0	0	0	0	242	0	137
Farm Gate Prices ($/t)	10-yr median	218	269	299	503	504	382	335	221	281	667	709	1090
	3-yr average	214	247	277	478	791	379	324	215	285	869	865	1066

* Cotton price calculated per tonne of bolls harvested assuming 40% is lint and 60% is seed

Commodity prices can be driven by the volatility of local and international demand and supply. Depending on the commodity, annual prices offered can be greatly different to the median price (Figure 1). These price ranges can be used to estimate the future possible range of prices. In figure 1, sorghum, wheat and maize had the lowest median price and lowest variance in price over the ten years. Therefore, even when the price is close to the quartiles (P=0.25 & 0.75 on the y-axis) the price is relatively unchanged (x-axis). Whereas chickpea, mungbean and sunflower median price is high and highly variable. For example, the 3-year average prices are 22-57% higher than the median price.

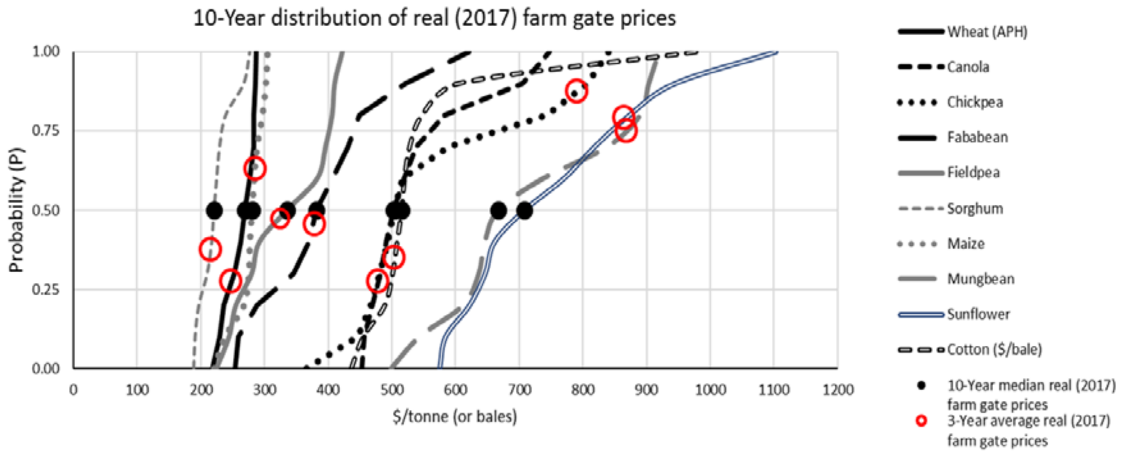


Figure 1. The probability distribution of annual average farm gate price of commodities (2008-2017) in the northern grain production region adjusted for inflation to 2017. The lowest annual price in this ten-year period is shown at P=0 on the y-axis and the highest price is at P=1. We used the 10-year median (P=0.5) prices as the expected price for our long-term economic analysis and compare this to the 3-year average price (2015-2017) (shown in red). Cotton price are given as $/bale (including lint and seed)

Economic performance of farming systems

As would be expected the total income and gross margins varied substantially across all sites, owing to the difference in rainfall, and hence crop productivity, and input costs required (Table 2 and Table 3). While we have used a common approach and assumptions for calculating total income, costs and gross margin returns across all sites, care should be taken when comparing the economic performance between sites. There are large yield, income and cost differences incurred between sites, due to differences in environmental (climate & soil) conditions, starting nutrient levels and weed status, which greatly influence the gross margin outcome between sites. For this reason, we focus mainly on comparing the economic outcomes between systems at the same site.

The difference between the best and worst system gross margins per location

Within each experimental comparison there was a significant gap between the best and the worst cropping system (Table 2 and Table 3). The difference between the highest grossing and lowest grossing system over the 4.5 experimental years (in $/ha/yr) was $410 at Billa Billa, $359 at Emerald, $269 at Mungindi, $296 at Narrabri, $176 at Spring Ridge, $169 at Trangie on red soil and $232 on grey soil, $285 for the mixed opportunity systems at Pampas, $332 for summer rotation systems at Pampas, and $494 for winter rotation systems at Pampas. The differences amongst rotations have declined over the past year due to the drought conditions limiting planting opportunities and hence total income has remained constant in most systems.

The best (or worst) system at each location was also not consistent. At most regional sites (except Emerald), the baseline cropping system designed to replicate current best management practice in a district performed the best or as well as any altered system. At Emerald, the high fertility systems performed the best, $118/ha/yr higher than the baseline. At Spring Ridge, the higher-legume system was the only system that resulted in higher economic returns of $60/ha/yr. If the lucerne crop had not been successful in the year of planting, then the baseline system would have been the best performing crop on grey soil. Amongst the Pampas systems, the gross margin returns of the baseline systems was exceeded by systems with higher legume frequency or crop diversity by $9 and $31/ha/yr, respectively over the experimental period.

Across all comparisons, the systems that produced the lowest gross margins were those where cropping intensity was altered. Higher crop intensity achieved the lowest gross margin at Billa Billa, Emerald, Spring Ridge and lower crop intensity the lowest GM at Mungindi (grain), Narrabri (ignoring crop diversity), and Pampas (mixed opportunity and winter themes). What this means is that getting cropping intensity wrong for your environment is a major driver of suboptimal system performance.

At Trangie, the ley pasture system resulted in higher returns of $71 and $140/ha/yr than the baseline system for the experimental period for the red and grey soil, respectively. The success of this system was due to good establishment of a lucerne crop in the early wetter years of the experiment, which has survived over the experimental period with periodic harvests. Whereas other cropping systems could not establish crops due to poor soil moisture. Overall, this highlights that there is a significant difference in the profitability of farming systems within a particular situation.

System modification effects on economics

While there was significant variation in the relative performance of different system modifications across sites, there were several consistent impacts from some of the system modifications.

- Higher nutrient strategy increased input costs significantly due to the higher fertiliser inputs to meet the crop nutrient budget that matched crop yield potential. Across all sites (except Emerald and Trangie red soil), this increased system costs and reduced total gross margins by $80-$610 per ha over the crop sequence (or $18-$136 /ha/yr). So far, we have seen few yield or economic responses to this higher nutrient supply approach (except Trangie – red soil and Emerald), so this reduced gross margins compared to the baseline, and resulted in lower return on costs at most sites.
- Higher crop diversity has not significantly altered the costs of the production system, though there are some notable site differences (Table 2). The performance of the alternative crops at each location has been the central driver of how these systems have performed relative to the baseline. Across the regional sites gross margins were between $296 and $1334 less over the whole crop sequence ($66-296/ha/yr lower) than the baseline system. At Pampas diversifying the cropping system has consistently exceeded the returns of the baseline crop sequence by between $138 and $987/ha over the 4.5 years ($31-219/ha/yr higher).
- Higher legume frequency systems have increased the variable costs of production in most cases, mainly due to higher costs for pesticides. While the Emerald and Spring Ridge sites there were marginally higher gross margins ($60-68/ha/yr) than the baseline, because of these higher costs they have a lower return on variable costs (ROVC) (Table 2 and Table 3).
- Lower crop intensity systems generally incurred lower costs but this was not universal across all sites; 5 of the 8 lower intensity systems had lower costs than the baseline with the 3 sowing cotton having similar or slightly higher costs. Despite the more conservative approach of waiting until the soil profile was full to sow a crop, this did not necessarily increase the outlay required to run such a system. At most sites, the maximum cash outlay required in the low intensity system was similar to the baseline, and in some cases lower (e.g. Spring Ridge). It would be expected that lower intensity systems would have lower costs and therefore may have higher ROVC than the baseline system, but this was not the case for all regional sites apart from Spring Ridge and Trangie red soil. And it is expected under more favourable conditions the baseline system would have had higher ROVC than the low intensity system. At Pampas, only the summer lower intensity system offered high ROVC, but this was not driven by savings in costs but rather higher income.

- Higher intensity systems did not increase total crop income at any of the sites and typically brought about an increase in costs, so that net returns were generally lower and the ROVC was dramatically lower. This highlights the risks associated with these systems. That is, over the relative dry run of years, these systems were working harder but not smarter than a more conservative cropping system. The high intensity system was up to $410/ha/yr behind the baseline system at Billa Billa, and even at the higher rainfall sites (Pampas, Spring Ridge, and Emerald) it was >100/ha/yr behind the baseline.

Table 2. Total revenue generated, costs of production (fertilisers, seed, operations, chemicals), gross margins (GM), the gap of a system to that the highest system GM per site, returns on variable costs (RVOC, ratio of income to costs), and the maximum cash outlay over the 4.5 years for each farming system tested at each of the 7 regional locations across the northern grains region.

Site	System	Total income ($/ha)	Total costs ($/ha)	Total GM ($/ha)	Gap from best ($/ha/yr)	ROVC	Max. cash outlay ($/ha)
Billa Billa	**Baseline**	**3901**	**839**	**3062**	**0**	**4.7**	**-317**
	Higher nutrient	3872	1055	2817	-54	3.7	-326
	Higher fertility	3590	1003	2587	-106	3.6	-321
	Higher legume	3597	1017	2581	-107	3.5	-306
	Crop diversity	3010	923	2087	-217	3.3	-352
	Higher intensity	2360	1144	1217	-410	2.1	-513
	Lower intensity	2305	852	1453	-358	2.7	-341
Emerald	**Baseline**	**3787**	**1492**	**2295**	**-118**	**2.5**	**-417**
	Higher nutrient	4090	1534	2556	-60	2.7	-422
	Higher fertility	4352	1528	2824	0	2.8	-417
	Higher legume	4115	1512	2603	-49	2.7	-395
	Higher intensity	2913	1706	1207	-359	1.7	-395
	Integrated Weed man.	4031	1972	2059	-170	2.0	-532
Mungindi	**Baseline**	**1590**	**643**	**947**	**0**	**2.5**	**-290**
	Higher nutrient	1504	909	595	-78	1.7	-313
	Higher legume	1495	727	768	-40	2.1	-290
	Crop diversity	669	537	132	-181	1.2	-351
	Lower intensity (cotton)	1297	752	545	-89	1.7	-297
	Lower intensity (grain)	375	638	-263	-269	0.6	-310
Narrabri	**Baseline**	**2569**	**1023**	**1546**	**0**	**2.5**	**-354**
	Higher nutrient	2265	1329	936	-136	1.7	-486
	Higher legume	2049	928	1121	-94	2.2	-354
	Crop diversity	1439	1227	212	-296	1.2	-633
	Higher intensity	2687	1177	1510	-8	2.3	-507
	Lower intensity	1707	797	910	-141	2.1	-451
Spring Ridge	**Baseline**	**3294**	**2166**	**1128**	**-60**	**1.5**	**-593**
	Higher nutrient	3363	2730	633	-170	1.2	-974
	Higher legume	3403	2006	1398	0	1.7	-712
	Crop diversity	2992	2160	832	-126	1.4	-593
	Higher intensity	2563	1960	604	-176	1.3	-731
	Lower intensity	2525	1480	1045	-78	1.7	-827
Trangie – red	**Baseline**	**1845**	**1021**	**824**	**-16**	**1.8**	**-324**
	Higher nutrient	2337	1444	894	0	1.6	-426
	Higher legume	1853	1049	804	-20	1.8	-363
	Crop diversity	1431	1049	382	-114	1.4	-363
	Lower intensity	1605	737	868	-6	2.2	-442
Trangie-grey	**Baseline**	**1217**	**713**	**504**	**0**	**1.7**	**-251**
	Higher nutrient	963	873	91	-92	1.1	-380
	Higher legume	1119	821	299	-46	1.4	-302
	Crop diversity	953	816	137	-82	1.2	-302
	Lower intensity	761	567	195	-69	1.3	-289

Table 3. Total revenue generated, costs of production (fertilisers, seed, operations, chemicals), gross margins (GM), the gap of a system to that the highest system GM per site, returns on variable costs (RVOC, ratio of income to costs), system WUE ($ gross margin/mm water use) and the maximum cash outlay achieved over 3.5 years for each farming system tested the core experimental site at Pampas across mixed opportunity, summer-dominated or winter-dominated cropping systems.

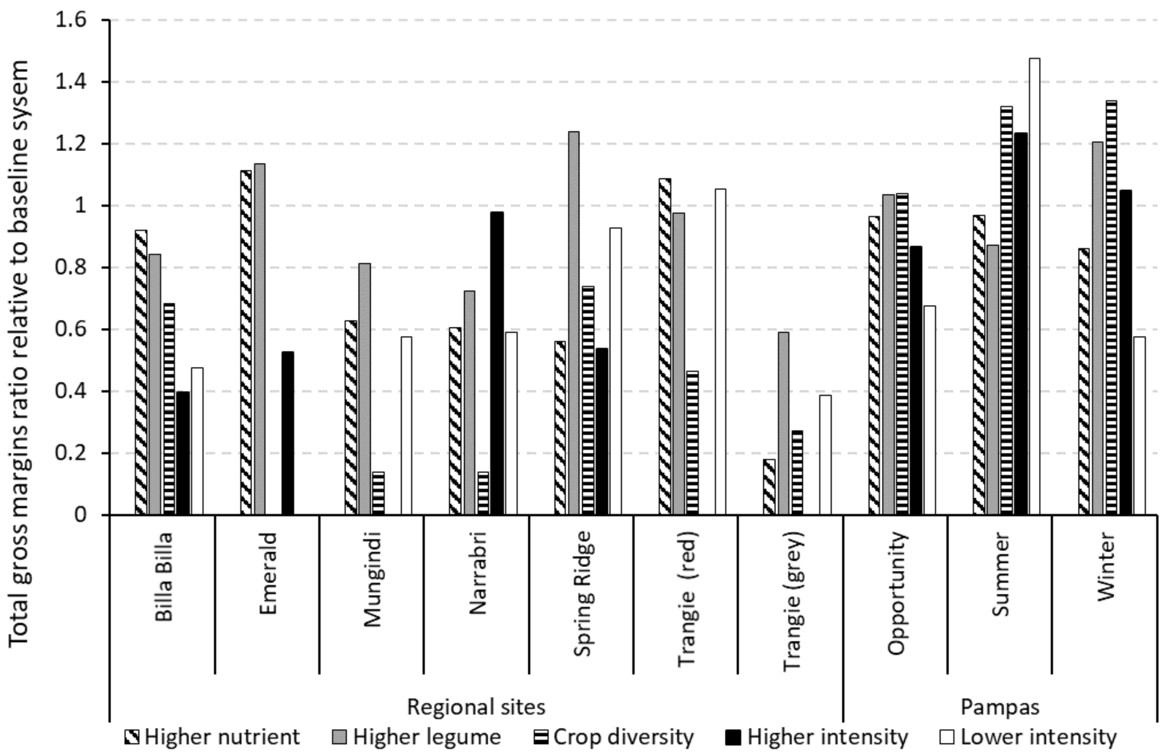
	System modification	Total Income ($/ha)	Total Costs ($/ha)	Total GM ($/ha)	Gap from best ($/ha/yr)	ROVC	Max. cash outlay ($/ha)
Mixed opportunity	**Baseline**	**4409**	**885**	**3524**	**-31**	**5.0**	-326
	Higher nutrient	4623	1223	3400	-58	3.8	-418
	Higher legume	4678	1032	3647	-3	4.5	-358
	Crop diversity	4665	1003	3662	0	4.7	-314
	Crop div. + nutrient	4371	1394	2977	-152	3.1	-491
	Higher leg. + diversity	4398	978	3420	-54	4.5	-346
	Lower intensity	3382	1002	2380	-285	3.4	-632
Higher intensity	**Baseline**	**4266**	**1218**	**3049**	**-9**	**3.5**	**-308**
	Higher nutrient	4358	1608	2750	-75	2.7	-358
	Higher legume	4105	1332	2773	-70	3.1	-334
	Crop diversity	4085	1081	3004	-19	3.8	-296
	Crop div. + nutrient	3977	1665	2312	-172	2.4	-471
	Higher leg. + diversity	4222	1134	3088	0	3.7	-328
Summer	**Baseline**	**3196**	**724**	**2472**	**-261**	**4.4**	**-382**
	Higher nutrient	3329	938	2392	-278	3.6	-426
	Higher legume	3073	921	2152	-332	3.3	-441
	Crop diversity	4170	906	3264	-85	4.6	-578
	Crop div. + nutrient	4197	1227	2970	-150	3.4	-650
	Higher leg. + diversity	4206	1048	3158	-108	4.0	-593
	Lower intensity	4351	705	3645	0	6.2	-317
Winter	**Baseline**	**3775**	**863**	**2913**	**-219**	**4.4**	**-445**
	Higher nutrient	3570	1064	2506	-310	3.4	-479
	Higher legume	4323	815	3508	-87	5.3	-237
	Crop diversity	4598	698	3900	0	6.6	-237
	Crop div. + nutrient	4252	1162	3090	-180	3.7	-430
	Higher leg. + diversity	4420	739	3680	-49	6.0	-220
	Lower intensity	2444	767	1678	-494	3.2	-441

Cross-site analysis of system profitability

While there are several interesting differences between different farming systems at each experimental location, here we examine across the full range of sites how modifications to the farming system that were common across several sites (i.e. higher nutrient, higher legumes, crop diversity, higher intensity, lower intensity) have influenced the economic performance compared to the baseline at each site. This was done by calculating the system total gross margins ($ GM/ha) and the return on variable costs (ROVC) ratio as a proportion of that achieved in the baseline (Figure 2). Hence, the baseline achieves a value of 1.0, and systems achieving 0.8 have a 20% lower value and systems achieving 1.2 have a 20% higher value for these economic metrics.

Across the various sites there are some variable and some consistent results in terms of the relative performance of the farming systems.

- Higher nutrient supply achieved a lower system total gross margin most sites (7 of 10 comparisons), due to the higher costs associated with supplying nutrients to satisfy a 90th percentile crop yield rather than fertilising for the median yield. Only at Emerald and Trangie red-soil did we observe a positive yield response to additional nutrient supply and hence this is the only location where system gross margins increased. However, the return on investment was similar at 20-30% lower ROVC ratios. At Mungindi the additions of more nutrient reduced grain yield and crop income in one year and added significantly to the costs of this system. We may expect this result under the challenging seasonal conditions we have experienced and with better seasonal conditions it might be expected to realise the benefits of such a strategy.
- Increasing legume frequency achieved 20-40% lower total gross margins at Billa Billa, Mungindi, Narrabri, and Trangie red-soil, at other sites gross margins were either higher or similar to system total gross margins in the baseline system. At Pampas the winter-legumes achieved 20% higher and the summer 13% lower gross margins than the baseline system. However, interestingly all ROVC ratios were within ±20% of the baseline system.
- Increase crop diversity resulted in 20-80% lower gross margins across all regional sites relative to the baseline system. However, at Pampas, diversity increased the summer and winter legume systems gross margins by 32%; the opportunity system was similar to the baseline. Few sites had significant soil-borne disease issues at the initiation of the study and hence rotational benefits have not yet been observed. The exception was Pampas where there have been rotation benefits for subsequent crops. This demonstrates that there can be significant costs or risks associated with implementing alternative crops to address weed or pathogen issues.
- Increased crop intensity had significantly lower total gross margin at all sites relative to the baseline system, with 20-30% lower total gross margins at Pampas. These systems also have higher costs and hence the return on investment is typically lower.
- Lower crop intensity systems have achieved 40-70% lower system total gross margins over the 4.5 years at most locations. However, it also resulted in 47% higher gross margins in the summer system at Pampas and returns were similar to the baseline at the Spring Ridge site.



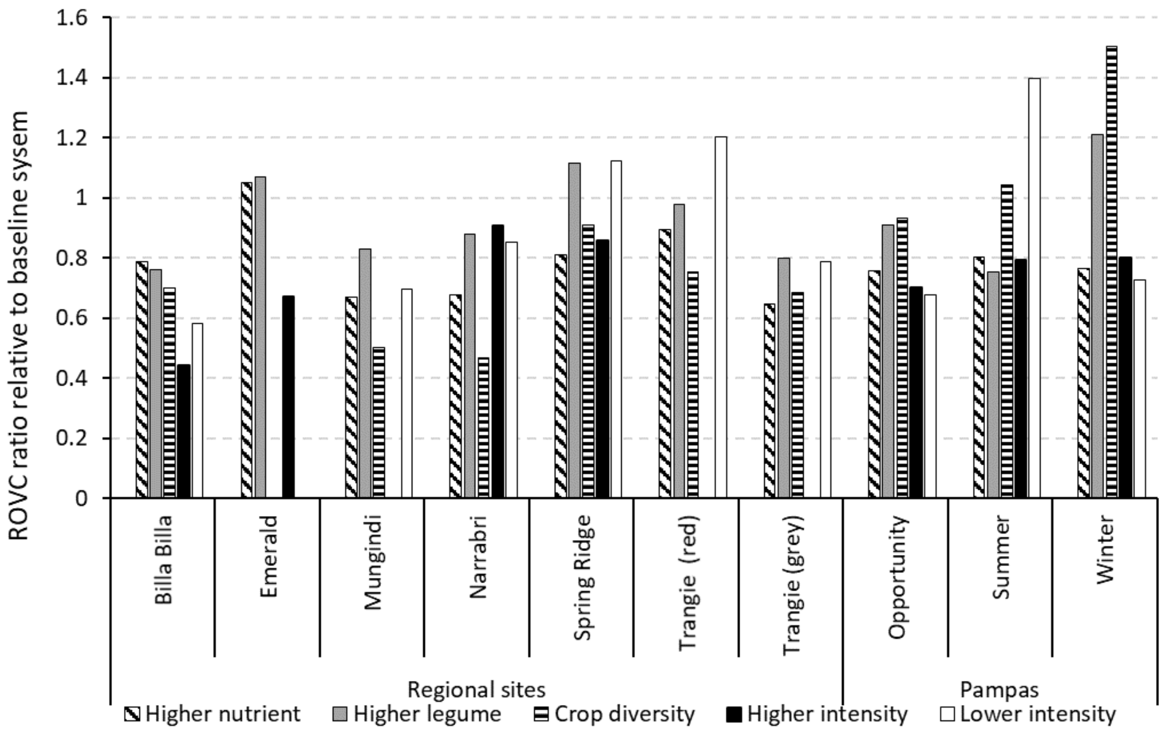


Figure 2. Relative system profitability of different farming systems as a ratio of the baseline system (i.e. 1 equals the baseline, higher is better and lower is worse) at 7 regional sites and under 3 different seasonal crops at the Core site (Pampas). Top shows the gross margin as a proportion of the baseline and the bottom the return on variable costs (ROVC) ratio relative to the baseline system

Impact of commodity price variability

The previous section has been based on the 10-year median commodity prices; however, as indicated by figure 1 some commodity prices can be more volatile than others. Therefore, the possible range of total gross margins for each system will be affected by the combination of commodities it produces. There is little correlation between the prices received for the different commodities here, i.e. the price of wheat does not affect the price of chickpeas.

Figure 3 and figure 4 show the system total gross margins using different combinations of crop grain prices for each of the trial sites and production systems at each site. On these figures, the median (P=0.5) total gross margin values are shown with the black dot and are the same as those presented in the above tables – correlating to 10-year median commodity prices. The values furthest to the left are the lowest probable GM and furthest to the right are the higher GM. The lines show the full range of combinations using the range of grain prices over the past 10 years, and the red dot is the system gross margin using the average price over the past 3 years. For example, at Billa Billa with the 10-year median commodity price for the baseline system total gross margins were $3062/ha (Table 2) and this could be as low as $2490/ha (when all commodity prices of that system are low) and as high as $4092/ha (when all commodity prices are high). Based on the last 3-year average price the returns of the baseline system would have been $3393/ha. Comparing this point, there is a 73% chance of getting lower returns in the future; or 27% chance of higher compared to historical prices. Higher legume prices in recent year has resulted in the baseline and higher legume systems to have above average returns at Billa Billa. Whereas lower sorghum and wheat prices has resulted in the other systems having below average returns.

It is notable that based on total gross margins, the ranking of systems rarely changes when using both the 10-year median commodity price and the actual price over the last 3-years for Billa Billa, Emerald, Mungindi, Narrabri and Trangie red-soil (Figure 3). For Mungindi, even when the higher crop diversity system had high prices (P=0.8) it still did not do better than the lower intensity system with low prices (P=0.2). At Spring Ridge the 10-year median commodity price ranked higher crop diversity ($832/ha; P=0.5) above higher intensity ($604/ha; P=0.5); however, based on the last 3-year average price the higher intensity ($1045/ha; P=0.8) was greater than the higher diversity ($652/ha; P=0.35). The ranking of systems at Trangie red soil also changed slightly with the 3-year pricing, however the baseline, higher legume and lower intensity systems offer similar gross margins and price risk for P=0 to 1.0. This information provides greater understanding of the risk and relative profitability as affected by grain prices associated with different systems.

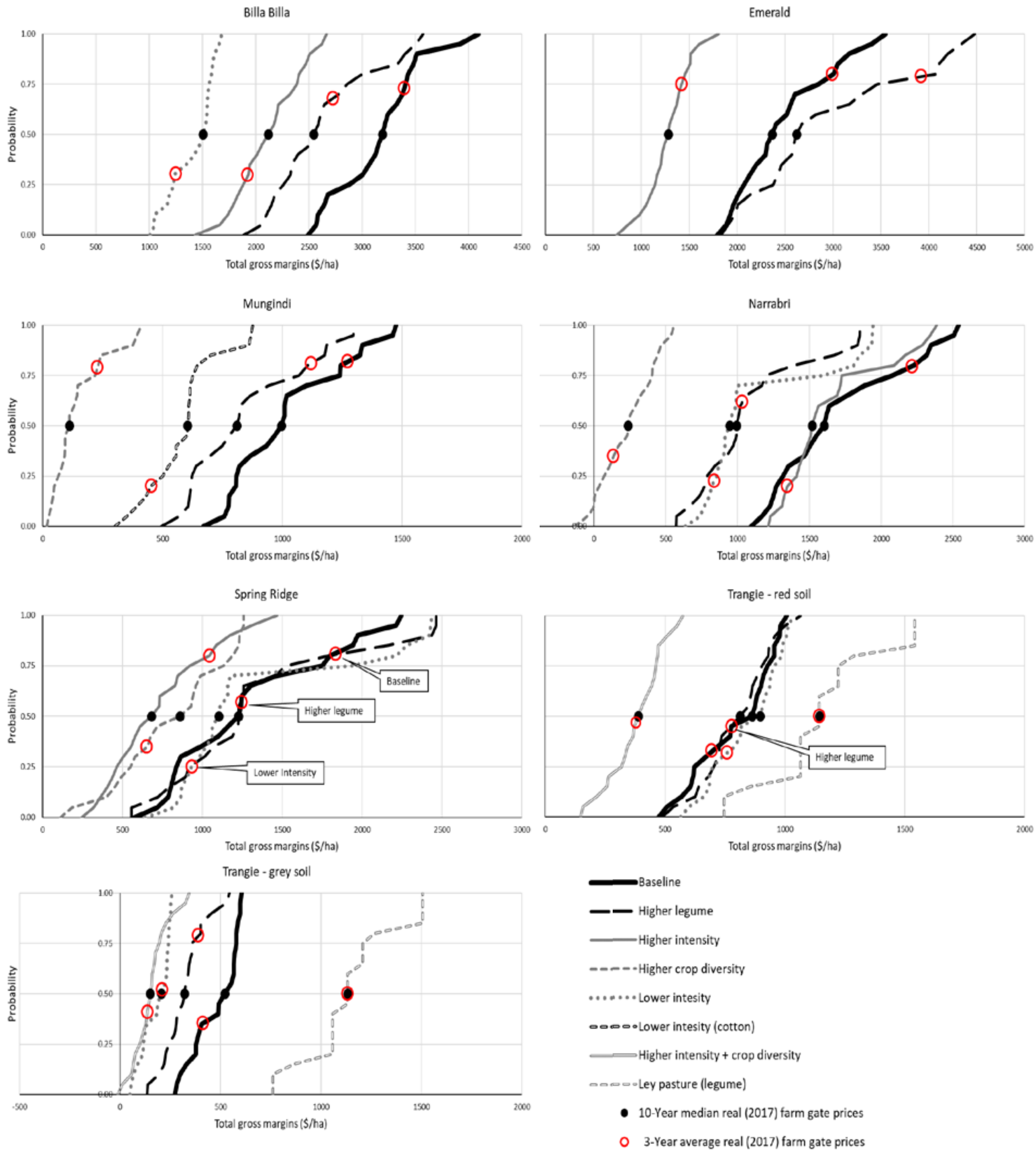


Figure 3. The distribution of total gross margins over 4.5 years calculated using the range of historical commodity prices for each farming system tested at regional locations across the NGR (Figure 1). The total gross margins with the lowest set of grain prices are shown where P=0 on and the highest combination of grain prices is shown where P=1. The median (P=0.5) total gross margins are the equivalent of our median price assumptions (shown in black dot), and the total gross margin using the 3-year average price (2015-2017) is in red.

At Pampas, variability in commodity prices would create significant differences in relative profitability amongst the different farming systems. Under the mixed opportunity systems, the higher crop diversity offers the highest expected outcome, and when all commodity prices are down (P=0.0) or high (P=1.0) it is still expected to outperform the other systems by offering higher total gross margins during the experimental period (Figure 4). Therefore, it had the highest returns and least risk of all the systems at that location with those 4.5 year climatic conditions. This was also the case for the winter-dominant cropping theme.

For the summer dominant system, 70% (P=0.7) of the time the lower intensity system benefited from better commodity prices; and 30% (1-0.7) of the time the higher diversity + legume system returned higher total gross margins due to favourable commodity prices. With the higher intensity theme, the median returns and variation of all cropping systems where similar - apart from higher legume. The latter had an 80% chance of offering lower total gross margins 80% of the time, with far lower returns with low prices (P=0.0) and even with high prices (P=1.0) they were only marginally better than the other cropping systems.

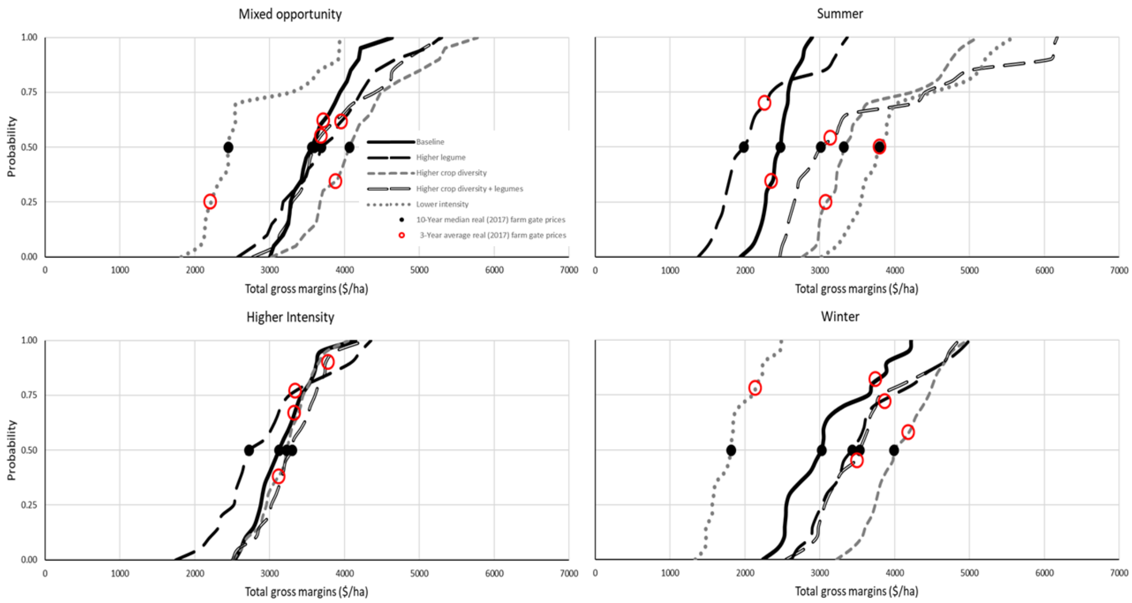


Figure 4. The distribution of total gross margins over 4.5 years calculated using the range of historical commodity prices for each farming system tested at the core experimental site, Pampas (Figure 1). The total gross margins with the lowest set of grain prices are shown where P=0 on and the highest combination of grain prices is shown where P=1. The median (P=0.5) total gross margins are the equivalent of our median price assumptions (shown in black dot), and the total gross margin using the 3-year average price (2015-2017) is in red.

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Panel discussion - Implications for crop sequencing decisions; how we manage water nutrition and disease; decisions in 2020 on soil water and crop sequence

Notes

Drought's drain: driving profit through supporting good mental health

Letitia Cross & Camilla Herbig, Rural Adversity Mental Health Program

Key words

farm profitability, mental health, stress management, decision-making

Take home messages

- Even though consultants haven't traditionally seen discussions with growers about stress management and mental health as part of their role it actually makes good business sense
- The 'slow creep' of drought-related stress is detrimental to growers if unaddressed, but supporting growers to understand and manage their stress helps to prevent developing mental health problems, while also supporting future relationships and business outcomes
- Consultants are skilled to support grower's decision-making, and this becomes crucial in adverse times to assist them to understand the facts, their options and ways of making informed decisions
- Recognising mental health concerns for a grower, having conversations and seeking support ensures not only the grower's wellbeing, but as interlinked businesses it also ensures the long-term profitability and viability of both consultants and suppliers.
- Looking after ourselves is essential so as we can cope with day to day stresses and support our families, friends, business and communities.

Background

Creating understanding and awareness of the importance of farmers actively looking after their mental health has not traditionally been a domain of the agriculture service industry. However, because of the co-reliance and linked economic fortunes it makes good business sense for consultants to consider the importance of having conversations with clients about proactively managing their stress and mental health during times of adversity.

Drought is particularly stressful due to the unpredictability and longevity of conditions. In spite of this, if clients are supported to consider their own stress management and mental upkeep as importantly as their equipment, rotational considerations or financial planning, they are positioned to not only survive drought but also to be mentally capable of capitalising on drought-breaking seasonal change. Additionally, this simple approach works to secure both financial and client longevity advantages for the consultant.

Droughts are a natural feature of the Australian environment. But unlike immediate disasters which feature a critical incident or rapid onset (fire, flood etc.), drought has been described as a 'creeping disaster'. This is because by the time a drought is identified, it is usually already well established, with mounting costs, and the opportunity to take proactive action has already been missed (Austin et al., 2018). The unpredictability and longevity of drought results in a cumulative effect, the 'slow creep', where stress which is held for long and unknown periods of time which makes it particularly detrimental. Left unaddressed this continually held stress is associated with negative personal, social, physical health and mental health consequences across time.

Taking action

Consultants, agronomists and broader agriculture service personnel have naturally been focussed on providing advice on the technical or product component of the farming business. There has also been a concern of consultants about overstepping social and personal boundaries to start conversations when living and working in interconnected small communities. However, genuine concern and open discussion is key to overcoming stigma around mental health, empowering people in rural communities to proactively identify, manage and seek help when required.

As consultants and agricultural support services are embedded in rural businesses they are uniquely positioned as independent and reliable sources of advice to support growers and rural communities during adverse times. A particularly important but often overlooked part of this advice is providing mental health and well-being support through general conversation and social connection. Having conversations which encourage clients to manage stress and maintain their mental health not only ensures growers continued productivity through capacity to operate, but as businesses are financially co-dependant it also preserves consultants own long-term profitability and viability.

Consultants with some knowledge and training can be a key contributor to identifying early signs of drought-related stress, through conversations to reduce stigma and encourage help seeking. This can be done in four simple ways:

1. Encourage stress management
2. Support good decision-making
3. Notice changes in clients, have the conversation and encourage help
4. Look after yourself, so you can continue to support others

1. Stress management

Stress is a normal reaction which everyone feels, as it is the physical and emotional response to having demands made upon us. However, the increasing load we carry and how we manage our stress has implications for our mental health, risk of developing an illness, decision-making and consequently operating a successful business.

Practicing stress management techniques in good times and in bad times is key to maintaining good mental health. So, some of the ways that people can be encouraged to better manage their stress includes:

- Try to take some time out and do things that you enjoy – even five minutes of 'putting the whir in our heads down' is beneficial
- Keep in touch with family, friends and neighbours – social connectedness is important
- Reflect on the good stuff – it is easy to fall into the negative in tough times but looking for the good creates balance in our thoughts and actions
- Eat well, sleep well and only use alcohol in moderation – you can't run on an empty tank.

2. Support good decision-making

A number of physical and emotional signs and symptoms of stress can impact wellbeing, concentration, motivation and ultimately decision-making ability. Understandably, when a person's behaviour is being compromised in this manner it is hard to focus on making effective personal and professional decisions.

This becomes particularly problematic in the agricultural industry given the high levels of uncertainty, the need for agility and the ability to make complex decisions associated with agricultural production enterprises. If someone is overstressed or suffering from a period of poor mental health, they have a limited ability to handle complex information; are more likely to make reactionary choices with less information; undertake higher risk options; or make no more decisions, which is still a decision. This type of compromised decision-making can have financial and long-term impacts on both the farming business and the consultant's business, so supporting effective and informed decision-making is critical. Five key ways to support clients in effective decision-making include:

- Prioritise decisions – depending on the size, impact and consequences and tackling one at a time
- Know your timeframe – understand the level of urgency for a decision to be made
- Consider options – laying out the cost, benefits and impacts of different options to make an informed decision
- Identify and utilise support network – utilise skills and technological knowledge of supports and professionals to assist
- Evaluate, reassess and adapt.

3. Notice changes in clients, have the conversation and encourage help

Notice the change - Sometimes being trusted, independent and reliable, consultants and agricultural service providers are often ideally located to notice a farmer's mental health in decline. Particularly when consultants visit clients regularly over a period of time. Some of the signs and symptoms that someone is struggling with their mental health include:

- Changes in mood or behaviour – e.g. low or flat mood or uncharacteristic anger or irritability
- Social withdrawal
- Feelings of panic, nervousness, being "on-edge", hopelessness and lack of interest in the future – showing signs or making statements to this effect
- Difficulty with usual tasks or activities – trouble concentrating, loss of interest, confidence, or motivation
- Effects on relationships – e.g. family breakdown or arguments
- Loss of interest in usually enjoyable things – e.g. hobbies, social occasions, events
- Low energy levels and unusual physical complaints (e.g. aches and pains)
- Changes in sleeping patterns and appetite
- Changing use of drugs or alcohol – generally increased or becoming more dependant.

A person doesn't have to be exhibiting all of these symptoms, but trust your instincts.

Have the conversation – While it can seem uncomfortable, checking on how someone is travelling and encouraging them to get help is just a conversation, and that's something we do every day. When having a conversation, make sure you have sufficient time, chat to the person in a comfortable place about what you have noticed and why you are concerned. You do not need to fix their problems but listen to their concerns and reassure the person that there is help available. Often just providing an opportunity for the person's concerns to be listened to can be of more value than you realise.

Some examples of ways to start this conversation include:

- "I haven't seen you around much lately… what's been happening?"
- "You look a bit run down, how are you going?"
- "I've noticed…"

Encourage help - If the person is not travelling well, then encourage them to act. There are many different types of help but a GP (General Practitioner) is a great first point of call. They can provide treatment options or a referral to another provider through a Mental Health Treatment Plan. There are also specialised clinicians (counsellor, psychologist & social workers); phone and online resources (Beyond Blue, Black Dog Institute, etc.); the NSW Mental Health Line - 1800 011 511; or for emergencies the Emergency Services (000). Help to source appropriate resources and services can also be gained through your local RAMHP Coordinator, www.ramhp.com.au and www.yougotthismate.com.au.

4. Looking after yourself

Supporting others can take its toll on you so it is important to look after yourself as well. You can:

- Debrief and reach out for support – utilise personal and professional networks to debrief after a difficult conversation or situation. In some workplaces, Employee Assistance Programs (EAP) are available to provide confidential support
- Do things you enjoy, be mindful, take some time out
- Eat well, sleep well and use alcohol in moderation
- Be active – physically, mentally, socially
- Set goals
- Practise gratitude and looking at the positives.

By understanding the impacts of stress in clients and ourselves we can employ stress management strategies, good decision-making practices, have conversations and look after ourselves to support our sector's resilience, maintain our profitability and be ready to jump when seasons turn.

Acknowledgements

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References

Austin, E.K, Handley, T, Kiem, A.S., Rich, J.L., Askland, H.A., Askarimarnani, S.S, Perkins, D.A. & Kelly, B.J. Drought-related stress among farmers: findings from the Australian Rural Mental Health Study. The Medical Journal of Australia 2018; 209 (4): 159-165. doi: 10.5694/mja17.01200

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Getting to the trusted advisor/grower relationship. Technical knowledge is only half the story!

Dennis J. Hoiberg, Lessons Learnt Consulting Pty Ltd

Key words

advisor, grower, relationships, business, management

Those of us who have, or wish for, a long advisory/consulting career with agribusiness have probably already recognised that effective relationships are based on more than just technical skills.

While these technical skills are fundamental for entry into "playing the game" they can only serve for so long. It's when we advisors realise that we need to go further than just providing technical skills that we move into the space of providing longer term relationship-based advice.

I don't have the expertise or credibility in providing advice as to how to apply technical skills, I do, however, have some expertise and experience in the strategies around human behaviour that can move the relationship to the exalted level of being a trusted advisor.

Some clues for you in getting to the trusted advisor status level with our grower clients include:

Play the long game

Understand that to get to the trusted advisor status requires both good and challenging times. It's not so much whether you were there for the good times that matter, but rather were you there for the bad times - the droughts, the fires, the family disputes and so on. The trusted advisor/grower is like a marriage without the benefits – in good times and bad, for richer or poorer. It takes time for trust to be developed by all parties, so recognise the long-term commitment that will be required. While playing the long game, don't drop the ball on the short-term stuff like contemporary technical knowledge. Invest effort in the long term. Develop a routine of meetings, networking, calling, emailing and generally staying in touch with people - even (in fact, especially) when you don't have anything to sell. Remember the value of "pastoral care".

It's not about you

It's about them, their businesses, challenges and lives. There will be times when the issues being faced by the client can't be met by you. There is no greater sacrifice than referring clients on to other sources – and no greater long-term benefit for your relationship with the client.

Get your ego and need for relevance under control.

There is a BIG difference between "wants" and "needs"

Take time out to know the difference between what a client wants and what they need. A critical characteristic of a trusted advisor is that they are curious about their client's ambitions, motivations and context. A trusted advisor should seek to understand in order to be understood.

Really understand the ambitions of your clients to appreciate where this request fits and how it will contribute to the achievement of them. Sometimes the best question to ask is "Why?" and the best piece of advice or answer is "No!"

You need to deliver

Quite simply, you need to do what you say you will and if you can't, then you must have a good reason and call it early.

No grower likes a surprise. They have enough of them in their everyday life. If the relationship is solid and built on both trust and success, the trusted advisor has a "few credits in the bank". However, understand the significance of making a withdrawal.

Should a "withdrawal" be made, the client needs to know early and be presented with a Plan B that they can choose to adopt. Don't leave clients in the lurch!

You must know your stuff

While I have said the trusted advisor relationship goes beyond technical advice, the technical advice is still important. Credibility built on authority is a major component of getting to and maintaining the trusted advisor status.

Maintain your skills level and ensure professional development is part of your calendar. Develop best practice ideas outside your industry.

Be respected – not liked

We all want to be liked. Unfortunately, as a trusted advisor this is not always possible. What's more important is that you are respected. To be respected, you must be all those things I have already spoken about as well as be prepared to make the hard decisions and the difficult "calls".

Trust will come from performance and who knows that may even result in being liked!

You are dealing with the "whole person."

Emotions are part of the relationship. Be comfortable displaying your own emotions and be comfortable responding to your clients' emotions. Empathy (not sympathy) is an important skill of the trusted advisor.

Be prepared to make emotional connections. Before this is possible, you need to be emotionally mature to allow yourself to respond to emotive situations.

Be comfortable sharing stories and sharing your lived experiences.

Love your work

Be enthusiastic. Show genuine energy. Display passion and people will follow you. Remember many of your clients have developed a keen "BS detector" and they can smell it kilometres away.

Have your own act together

A large part of your credibility and your "right to be at the table" is your own being. Look after yourself and present yourself as a professional. Live by our values, surround yourself with great people and give freely of your personality, energy and experience. Be authentic and real.

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Day 2 early risers session

Implications of continuing dry conditions on cereal disease management

Steven Simpfendorfer, NSW DPI, Tamworth

Keywords

fusarium crown rot, rhizoctonia root rot, PREDICTA® B, spot form of net-blotch

GRDC code

DAN00213: Grains Agronomy & Pathology Partnership - A strategic partnership between GRDC and NSW DPI

Take home messages

- Due to a combination of factors there is likely to be increased cereal plantings in 2020, once the opportunity arises
- Failed pastures with decent levels of grass development are potentially high risk scenarios for cereal diseases in 2020 as grasses host many of the causal pathogens
- Unfortunately, prolonged dry conditions increase the risk of cereal diseases including Fusarium crown rot and rhizoctonia root rot
- However, steps can be taken to minimise impacts which include:
  1. Know before you sow (e.g. PREDICTA®B)
  2. Implementing pre-sowing management options
  3. Sowing quality seed known to have both good germination and vigour
  4. Assessing root health and infection levels around heading – you need to 'dig deeper' than just leaf diseases!

Introduction

Unfortunately, much of central NSW experienced a relatively dry winter cropping season again in 2019. These conditions, especially with hotter and drier conditions during grain filling, are ideal for the expression of Fusarium crown rot as whiteheads and resulting yield loss. Fusarium crown rot, caused predominantly by the stubble-borne fungus *Fusarium pseudograminearum*, infects all winter cereal crops (wheat, barley, durum, triticale and oats) and numerous grass weed species also host this pathogen. However, a key point is that dry conditions do not just have implications for Fusarium crown rot management. There are other potential cereal disease implications that need to be considered by growers and management strategies implemented to maximise profitability when recovering from drought.

Extended dry conditions in 2018 and 2019, possibly longer in some areas, has a range of potential implications on farming systems which can include:

- Reduce stubble cover – increasing wind erosion, reducing fallow efficiency and limiting stored soil moisture levels
- Reduced decomposition of crop residues which can extend inoculum survival to 2 to 4+ years
- Reduced animal stock numbers – extended dry has seen sheep and cattle numbers decline which will take a number of seasons to recover
- Reduced survival of pastures in mixed cropping systems
- Later seasonal breaks reducing opportunities for canola establishment in some districts

- Widespread baling of cereal crops for hay in 2018 and 2019
- Increased pressure on available planting seed for establishing crops in 2020.

Although many of these issues are common across continuous and mixed cropping enterprising, as a general rule those operations that have opted for more intensive broadacre crop production are hopefully more aware of potential pitfalls around limiting cereal diseases and ensuring quality of planting seed. The lack of animal stock, failure of pastures and need for ground cover is likely to see a substantial increase in the area of cereals planted, especially in mixed farming systems once the drought breaks. Grass species and grass weeds tend to dominate as legume species decline in pasture mixes over time and with moisture stress. These are therefore potentially higher risk paddocks for cereal diseases as the grasses serve as alternate hosts for pathogens such as *Fusarium pseudograminearum* (Fusarium crown rot), *Bipolaris sorokiniana* (common root rot), *Rhizoctonia solani* (rhizoctonia root rot), *Gaeumannomyces graminis* var. *tritici* (take-all), root lesion nematodes and some leaf diseases (e.g. barley grass hosts net-blotch pathogen *Pyrenophora teres*).

When the drought does break in impacted regions, hopefully in 2020, growers will be driven by two key factors. The first will be to generate cash flow and the second will be to restore groundcover to bare paddocks through the planting of winter cereals. This will potentially occur with little regard to the risk posed by plant pathogens and the quality of available planting seed. Maximising the profitability of crop production is going to be critical to many farming operations once the drought breaks. The following paper highlights some of the potential issues for consideration by growers and agronomists from a cereal pathology view point. Some practical steps that can be taken to hopefully minimise losses are also outlined.

Step 1: Know before you sow

Although paddock history can be a good guide to potential disease issues, extended dry conditions can allow damaging inoculum levels to still persist from 2-4+ seasons ago. Hence, growers need to consider the longer-term sequences within paddocks. How cereal stubble was handled over prolonged dry conditions can also influence the survival and distribution of cereal pathogens. Paddock history is only a guide and provides no quantitative information on the actual level of risk posed by different cereal diseases.

Consider testing paddocks using PREDICTA®B. This would be especially useful for paddocks coming out of failed pastures which may have become dominated by grasses. PREDICTA®B is a quantitative DNA based soil test which provides relative risk or population levels for a wide range of pathogens that can be used to guide management decisions. However, ensure you are using the latest recommended PREDICTA®B sampling strategy which includes the addition of cereal stubble to soil samples (see useful resources). Addition of cereal stubble (or grass weed residues if present in pasture paddocks) improves detection of stubble-borne pathogens which cause diseases such as Fusarium crown rot, yellow spot in wheat and net-blotches in barley. Considerable GRDC co-funded research has been conducted nationally over the last 5 years to improve the recommended sampling strategy, refine risk categories and include additional pathogens or beneficial fungi (AMF) on testing panels. Recent paddock surveys have highlighted that a single pathogen rarely exists in isolation within individual paddocks but rather multiple pathogens occur in various combinations and at different levels. PREDICTA®B is world leading technology that can quantitatively measure these pathogen combinations within a single soil + stubble sample. Given extended dry conditions the two key cereal diseases of concern for 2020 in central NSW are likely to be Fusarium crown rot and rhizoctonia root rot. The risk of both of these diseases can be determined by PREDICTA®B.

Alternately, cereal stubble or grass weed residues can be collected from paddocks and submitted to NSW DPI laboratories in Tamworth as a 'no charge' diagnostic sample (see contact details). Samples are plated for recovery of only two pathogens which cause Fusarium crown rot or common root rot and provide no indication of other potential disease risks.

Step 2: Consider pre-sowing management options

Generic management options are provided with PREDICTA®B test results which are tailored to the actual levels of different key pathogens detected within a sample. Your PREDICTA®B accredited agronomist should also be able to assist with interpretation which can be daunting given the number of pathogens covered by the testing. NSWDPI are also happy to discuss results (PREDICTA®B or stubble testing) and work through potential management options (see contact details).

Assuming main concern is **Fusarium crown rot**. Based on the following PREDICTA®B or stubble test results pre-sowing management options include:

Below detection limit (BDL) or low:
No restrictions, ensure good crop agronomy

Medium:
Consider sowing a non-host pulse or oilseed crop with good grass weed control.

If sowing cereal then:

- Avoid susceptible wheat or barley varieties, durum is higher risk but oats are fine
- Sow at the start of a varieties recommended window for your region
- Consider inter-row sowing (if previous cereal rows are still intact) to limit contact with inoculum
- Do not cultivate - it will spread inoculum more evenly across paddock and into infection zones below ground
- Be conservative on nitrogen application at sowing (Figure 1) as this can exacerbate infection (e.g. consider split application) but ensure a maintenance level of zinc is applied
- Be aware that current seed treatments registered for Fusarium crown rot suppression provide limited control
- Determine infection levels around heading (see step 4).

High:
Consider sowing a non-host pulse or oilseed crop with good grass weed control.

If sowing cereal then:

- Choose a more tolerant wheat or barley variety for your region to maximise yield and profit (Table 1), durum is very high risk with yield loss >50% probable in a tough finish but oats are still a decent option
- Sow at the start of a varieties recommended window for your region as this can half the extent of yield loss
- If a late break occurs consider switching to a quicker maturing wheat variety or go with barley to limit exposure to heat stress during grain filling which exacerbates yield loss
- Consider inter-row sowing (if previous cereal rows are still intact) to limit contact with inoculum
- Do not cultivate - it will spread inoculum more evenly across paddock and into infection zones below ground
- Be conservative on nitrogen application at sowing (Figure 1) as this can exacerbate infection (e.g. consider split application) but ensure a maintenance level of zinc is applied

- Be aware that current seed treatments registered for Fusarium crown rot suppression provide limited control and get to a Syngenta learning centre in 2020
- Determine infection levels around heading (see step 4) and be prepared from sowing to cut for hay or silage if required.

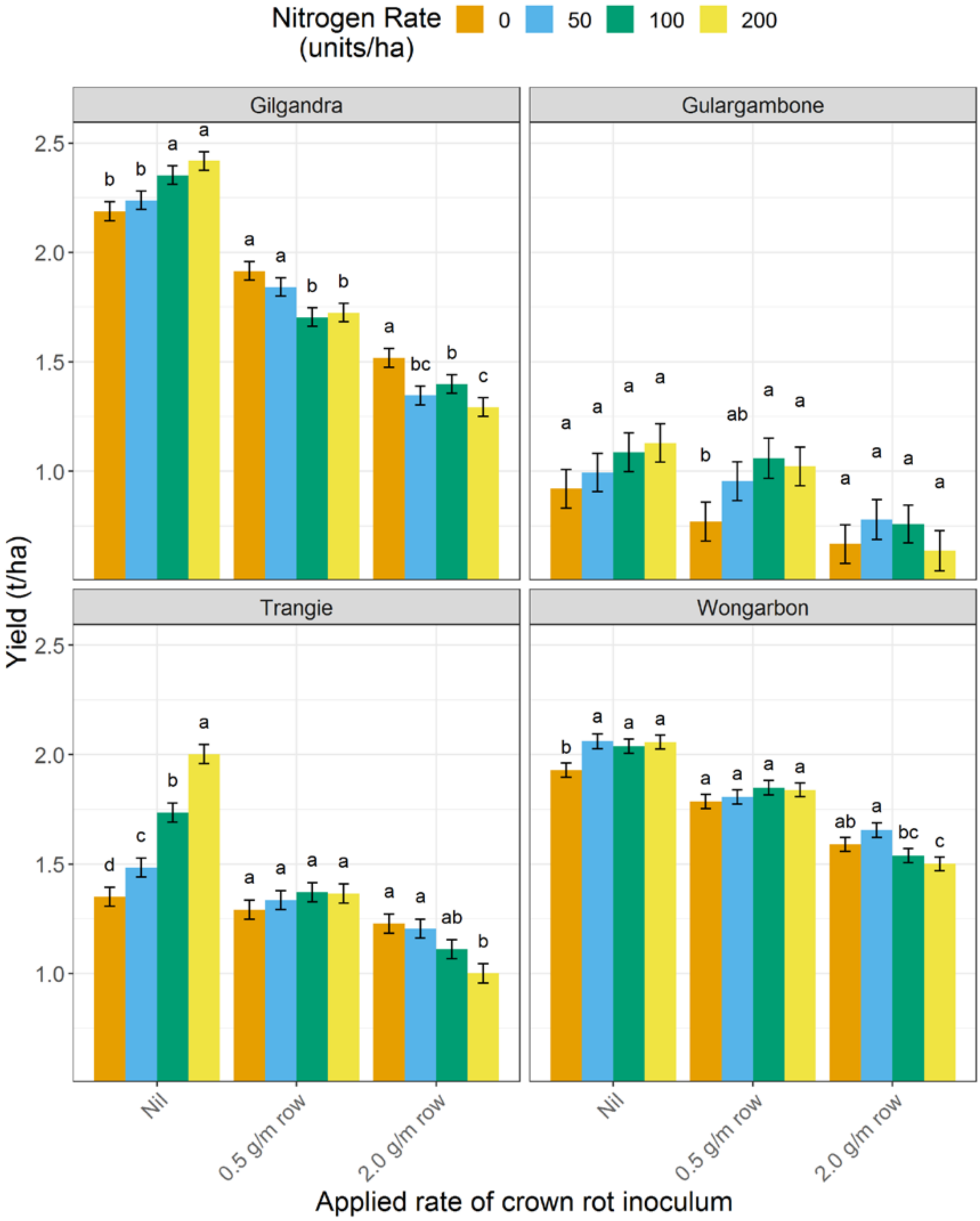

Figure 1. Interaction of nitrogen nutrition and crown rot infection on bread wheat (Suntop⊕ and EGA Gregory⊕) yield across four sites in central NSW in 2018.
Note: Nil applied inoculum represents a BDL/low risk, 0.5 g/m row a medium risk and 2.0 g/m row a high risk of crown rot infection.

Table 1. Average yield (t/ha), yield loss from crown rot (%), screenings (%) and lost income from crown rot ($/ha) of four barley, 5 durum and 20 bread wheat entries in the absence (no added CR) and presence (added CR) of crown rot inoculum averaged across 50 sites in central/northern NSW and southern Qld – 2013 to 2017.
Varieties within crop species ordered from highest to lowest yield in added CR treatment. Lost income and income in added CR treatment based solely on reduced yield (t/ha) in added CR treatment or absolute yield (t/ha) in this treatment multiplied by average grain price of $220/t for barley, $240 for AH and $300/t for APH bread wheat and $350/t for durum. Grain quality impacts and variable costs including PBR not considered.

Crop	Variety	Quality Class.	Yield (t/ha)		Yield loss	Screenings (%)		Lost income from crown rot	Income added CR
			No added CR	Added CR	(%)	No added CR	Added CR	($/ha)	($/ha)
Barley	La Trobeᶲ		4.17	3.59	14.0	6.5	8.4	128	790
	Spartacusᶲ		4.18	3.58	14.3	2.9	4.6	131	788
	Commanderᶲ		4.09	3.40	16.8	6.1	8.2	151	748
	Compassᶲ		4.20	3.39	19.4	2.1	2.9	179	745
Durum	Lillaroiᶲ		3.79	3.00	20.8	3.2	5.9	275	1050
	Bindaroiᶲ		3.88	2.92	24.7	2.7	5.8	336	1023
	Jandaroiᶲ		3.48	2.64	24.3	4.1	9.2	296	923
	Caparoiᶲ		3.34	2.20	34.1	9.0	16.5	399	770
	AGD043		2.72	1.65	39.1	3.8	13.8	372	579
Bread wheat	Beckomᶲ	AH	4.57	3.94	13.9	8.8	12.7	153	944
	Mustangᶲ	APH	4.17	3.67	11.9	5.2	7.0	148	1102
	Mitchᶲ	AH	4.08	3.51	13.9	7.7	10.2	136	842
	Reliantᶲ	APH	4.18	3.50	16.3	5.3	8.1	204	1051
	Suntopᶲ	APH	3.99	3.46	13.3	7.3	9.6	160	1037
	Sunguardᶲ	AH	3.81	3.35	12.0	6.2	8.7	110	804
	Spitfireᶲ	APH	3.86	3.34	13.3	5.8	8.0	154	1003
	Gauntletᶲ	APH	3.92	3.29	16.1	4.4	7.0	189	987
	Lancerᶲ	APH	3.88	3.27	15.8	4.8	7.1	184	981
	Sunmateᶲ	APH	4.02	3.23	19.6	6.4	9.7	237	969
	Coolahᶲ	APH	4.03	3.21	20.4	5.8	9.4	247	962
	Flankerᶲ	APH	4.04	3.12	22.8	6.0	10.4	277	936
	Dartᶲ	APH	3.73	2.99	19.9	9.3	12.8	223	897
	EGA Gregoryᶲ	APH	3.90	2.89	25.9	6.7	11.4	303	868
	Vikingᶲ	APH	3.48	2.89	17.1	10.9	16.8	179	866
	Lincolnᶲ	AH	3.88	2.78	28.3	8.6	12.8	264	668
	Crusaderᶲ	APH	3.43	2.76	19.4	8.3	13.4	199	829
	QT15064R	APH	3.68	2.73	25.7	8.3	15.1	284	819
	Suntimeᶲ	APH	3.43	2.62	23.6	10.6	17.2	243	787
	Strzeleckiᶲ	AH	3.03	2.17	28.3	12.0	18.0	206	521
		Lsd (P=0.05)	*max. 0.137*			*max. 1.37*			

Note: The extent of yield loss associated with crown rot infection varied between seasons and sites being 21% in 2013 (range 13% to 55% across nine sites), 22% in 2014 (range 6% to 47% across 12 sites), 18% in 2015 (range 7% to 42% across 12 sites), 13% in 2016 (range 6% to 29% across 11 sites) and 29% in 2017 (range 20% to 45% across six sites) averaged across varieties.

Assuming the main concern is **rhizoctonia root rot (AG8)**, which is particularly favoured in lighter red soils**.** Based on the following PREDICTA®B test results pre-sowing management options include:

Below detection or low:
No restrictions, ensure good crop agronomy.

Medium or high:
Consider sowing a non-host pulse or oilseed crop with good grass weed control.

If sowing a cereal then:

- Avoid pre-sowing sulfonylurea herbicides which can restrict early root growth which exacerbates infection
- Consider slightly increasing sowing rate to compensate for potential tiller losses
- Plant at the start of a varieties recommended window for your region as more rapid root growth in warmer soil allows the primary root system to escape significant infection
- Sow wheat instead of barley as it is less susceptible to rhizoctonia, oats are also a good option
- Soil disturbance below the seed (ideally 5-10 cm) at sowing promotes rapid root growth away from rhizoctonia and disrupts the hyphal network, risk is greater with single disc seeders than knife points
- Ensure good nitrogen and phosphorus nutrition as deficient crops are more susceptible
- Current seed treatments registered for rhizoctonia suppression provide useful but limited control, fungicides applied through in-furrow liquid banding can provide improved levels of rhizoctonia suppression
- Assess root health coming into Spring (see step 4).

Step 3: Ensure quality of planting seed

Seed retained for sowing is a highly valuable asset and the way it was treated at harvest and in on-farm storage during summer, or between seasons, is critical to ensure optimum germination potential and crop establishment in 2020. Retained seed can be tested for vigour, germination, purity/weed seeds and disease pathogens. It is advisable to undertake testing at least two months before sowing so that an alternate seed source can be organised if required. Grading to remove smaller grains which inherently have reduced vigour can also improve the quality of planting seed.

Vigour and germination tests provide an indication of the proportion of seeds that will produce normal seedlings and this helps to determine seeding rates. Particular attention should be given to determining vigour of retained seed for sowing in 2020 due to seasonal conditions in 2018-19. Vigour will be even more important if growers plan to increase sowing depth to capture an earlier sowing opportunity through moisture seeking.

NSW DPI, Tamworth normally provides pathology testing of winter cereal seed for common seed-borne fungal pathogens which will continue in 2020. Germination is also noted but this only tells growers how much of their seed is alive with the main purpose of testing to determine levels of fungal infection present. Testing will be extended for the 2020 pre-season to also provide an indication of vigour and emergence which should be used as a guide only (see contact details).

A comprehensive GRDC fact sheet outlining issues with retaining seed after challenging seasons is available from the GRDC website (see useful resources). The fact sheet outlines how growers can test their own seed. Alternatively, a range of commercially accredited providers of both germination and vigour tests are available.

Seed treatments containing fluquinconazole, flutriafol or triadimenol, can reduce coleoptile length in cereals and cause emergence issues under certain conditions. These active ingredients should be avoided if sowing seed with potentially lower vigour, sowing deeper, sowing into cooler soils, in soils prone to surface crusting or where herbicides such as trifluralin have been applied.

Step 4: Assess infection levels and root health prior to head emergence

Improved agronomy has considerably reduced the impact of rhizoctonia root rot (e.g. early sowing, grass free canola, pulse and pastures, knife point seeding systems and fungicides). These changes in agronomy have resulted in a significant shift in the symptomology of rhizoctonia root rot from 'bare patches' due to seedling infection to development of uneven growth in mid-winter due to infection of crown roots when soil temperatures drop to <10°C. Infection can then continue to develop on the crown roots until the crop matures, and can spread to the seminal root system, limiting water uptake in periods of high evapotranspiration and nutrient limitation. Hence, there is the potential for crown root infection by rhizoctonia to go unnoticed in paddocks as wavy and uneven growth is often associated with a range of other factors. This situation can be easily identified with the help of a shovel or spade! Simply dig up some plants around heading, wash soil away from roots and inspect the general root health - paying particular attention to whether the crown roots are restricted with a 'spear tip' appearance. Alarmingly, if seasonal conditions have been good prior to heading, crops with significant rhizoctonia infection of crown roots can appear quite normal but have severely compromised root systems. If the season stays wet with milder temperatures, then infected crops can sneak through with minimal yield loss. However, these same crops are likely to suffer dramatically if drier and warmer conditions are predicted during heading and grain filling.

This is a very similar situation to Fusarium crown rot which can also go unnoticed in paddocks until dry and hot conditions during grain filling trigger the expression of conspicuous whiteheads. However, honey-brown discolouration at the base of infected tillers can be used to determine the extent of Fusarium crown rot infection prior to heading. Simply dig up plants (inspect root health at the same time as above), ensure leaf sheathes at the base of tillers are removed and visually inspect for brown discolouration.

Assessing root health and Fusarium crown rot infection levels around heading allows a grower to make an informed decision at this point in time given seasonal predictions (e.g. cutting for hay or silage, reduce further input costs) rather than simply letting the weather dictate the outcome. Although this would be a less than an ideal situation, such tough decisions can still maximise profitability or minimise losses under these scenarios.

Other potential implications of dry conditions – learnings from north NSW in 2019

Dry conditions can also impact on the lifecycle of necrotrophic fungi which cause yellow spot in wheat or net-blotches in barley. We observed this around Croppa Creek in northern NSW in 2019 with spot form of net-blotch (SFNB) in barley crops. Numerous barley crops in a restricted area had decent levels of SFNB lesions on leaves during tillering. This was surprising as the season was relatively dry up to this point with only low rainfall events (<5 mm) since sowing. Rainfall while limited, was accompanied by early morning fogs. These conditions, while not really contributing to yield potential, were enough to meet the 6 hours of high humidity (>80% RH) to initiate SFNB infections on leaves. Interestingly, due to dry conditions the primary infection propagules (pseudothecia) which have a moisture requirement had not matured on 2018 barley stubble. The primary source of infection was mature pseudothecia present on 2017 or even 2016 barley stubble.

SFNB was also present in two barley crops sown into wheat stubble which was surprising. However, conidia of the net-blotch fungus *Pyrenophora teres* formed on collected wheat stubble after 4 days in humid chambers. This supports 2018 disease survey findings where the SFNB fungus was found to be saprophytically infecting wheat crops due to late rainfall in October, coinciding with senescence of lower wheat leaves.

High levels of SFNB were also present in two barley crops in this same region in 2019 where seed was treated with the fungicide Systiva®. Reduced sensitivity to this SDHI active (fluxapyroxad) was confirmed by the Curtin University fungicide resistance group in net form of net-blotch (NFNB) populations on the Yorke Peninsula of SA in 2019. Pure SFNB isolates collected from these northern NSW barley crops were sent to Curtin University and were shown to have **no** reduced sensitivity to fluxapyroxad. In our situation we suspect that dry conditions around the seed prevented Systiva from dissolving into the surrounding soil, limiting uptake through the roots and movement through the plant into leaves. Seedlings had established well and their root systems had penetrated into deeper soil moisture which was allowing them to progress, but the top 10 cm of soil was very dry with little visual loss of red pigmentation from the seed treatment on seed coats at the time of inspection.

Conclusions

The perpetual risk as a plant pathologist is the perception that we are always the bearer of bad news or the 'grim reaper mentality'. Elevated risk of stubble- and soil-borne diseases in 2020 is inevitable given continuing dry conditions which have prolonged survival of pathogen inoculum. However, practical steps can be taken to identify the level of risk and strategies implemented to minimise but not necessarily fully eliminate disease impacts on wheat and barley crops in 2020. Hopefully wet conditions restrict impact of the two most likely cereal disease risks (Fusarium crown rot and rhizoctonia root rot). However, growers and their agronomists need to be prepared to inspect the root health and stem bases of cereal crops around heading to guide some potentially tough but informed decisions. NSW DPI plant pathologists are also available throughout the season to provide support.

Useful resources

https://grdc.com.au/resources-and-publications/groundcover/ground-cover-supplements/groundcover-issue-130-soil-borne-diseases/correct-sampling-a-must-to-accurately-expose-disease-risk

https://grdc.com.au/__data/assets/pdf_file/0028/186139/grdc-tips-and-tactics-rhizoctonia-southern-print-version.pdf.pdf

https://grdc.com.au/resources-and-publications/all-publications/factsheets/2011/01/grdc-fs-retainingseed

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Managing chickpea diseases after the drought

Kevin Moore, Steve Harden, Kristy Hobson and Sean Bithell, NSW DPI, Tamworth

Key words

chickpea, disease risk, Ascochyta, Phytophthora, Sclerotinia, root lesion nematode (RLN), management, fungicide rain fastness

GRDC code

Grains Agronomy & Pathology Partnership - A strategic agreement between GRDC and NSW DPI (DAN00213): BLG209 Pulse Integrated Disease Management – Northern NSW/QLD

Take home messages

- Do not underestimate disease risks after a drought – pathogens survive longer and can still threaten your 2020 chickpea crops
- Unless you are in a high risk Ascochyta situation, it is unlikely there will be a cost benefit applying a foliar fungicide to 2020 crops until after the disease is detected
- However, if you are at a high risk of Ascochyta, apply a foliar fungicide before the first post emergent rain event
- High risk situations include planting into paddocks with active Ascochyta inoculum and planting seed that has not been properly treated
- Recent research has shown the Ascochyta fungicides Aviator Xpro and Veritas are rain fast (up to 100 mm rain in 150 minutes)
- Phytophthora and Sclerotinia levels will not have declined much during the drought and pose a medium to high risk in 2020
- Root Lesion Nematodes may have declined during the drought but if numbers at the start of the drought exceeded 10/g soil, it may still be sufficient to cause damage in 2020 chickpea crops.

How drought affects plant diseases

- Drought reduces the breakdown of plant residues. This means that inoculum of some diseases does not decrease as some might expect and will carry over for more than one growing season. The expected benefits of crop rotation may not occur
- Bacterial numbers decline in dry soil. Some bacteria are antagonists of soil borne fungal diseases. These diseases can be more severe after drought
- Abandoned, or drought stressed crops still set seed. Summer/autumn rains can lead to large numbers of volunteers. Low stock numbers make it difficult to control these volunteers, which can host Ascochyta, viruses and virus vectors, and other pathogens
- Weeds that are stressed by drought may be harder to kill and can harbour pathogens
- Soil water and nitrogen may be unbalanced and these are likely to impact diseases in 2020 and beyond.

Chickpea disease risks after the drought and advice for 2020 chickpea farmers

- Ascochyta is unlikely to cause widespread problems in 2020 unless it is wetter than average as inoculum levels have not increased in past two seasons and even if infected with Ascochyta, all varieties recover well during dry conditions. For these reasons, unless you are in a high risk situation, there will be no cost benefit applying Ascochyta fungicides until the disease is detected. High risk situations include planting into paddocks where active inoculum is known to be present (see following examples at Tulloona and Moree) and planting seed of unknown pathogen status that has not been properly treated. In these situations, apply an Ascochyta fungicide before the first post-emergent rain event, then monitor the crop 10-14 days after rain.

- If Ascochyta is detected, apply a registered fungicide before the next rain event. This is especially important during the reproductive stage as Ascochyta on pods causes abortion, seed infection and seed defects. If you miss a spray; fungicides with limited curative activity are now available however they have a limited time of use and tight intervals for application after an infection event occurs. (https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2019/02/chickpea-ascochyta-research-what-if-i-miss-a-spray-are-there-salvage-options-with-new-chemistry-how-long-do-fungicides-persist)
- Under drought conditions, some plant pathogens survive longer than normal; Ascochyta inoculum for 2020 chickpea crops may have originated in 2017 or even 2016. In August 2019, volunteer chickpeas in a crop of wheat at Tulloona had Ascochyta lesions. That paddock had grown chickpeas in 2016 (under high Ascochyta pressure); wheat in 2017 and chickpeas in 2018 (crop abandoned due to drought). Rain in Oct/Nov 2018 allowed Ascochyta to develop on abandoned plants, and seed left in the paddock germinated on rain in March 2019 to produce the volunteers that got infected during rain events in May, June and July 2019. Another example of how drought can prolong survival of inoculum was provided in August 2019, when we received chickpea stubble from a paddock at Moree that had grown chickpeas in 2017. The stubble contained fungal fruiting bodies. We soaked the stubble in water for several hours then applied the water suspension to chickpea seedlings; 7 days later symptoms and pycnidia of Ascochyta developed on the seedlings, proving that the inoculum had persisted on the nearly two-year old chickpea residue. Both the Tulloona and Moree paddocks are considered high risk if planted to chickpeas in 2020.
- Remember, the Ascochyta fungus is evolving: In our 2010 Tamworth disease management trial, unprotected PBA HatTrick⍭ (then rated moderately resistant (MR)), lost 37% yield to Ascochyta; while in the 2016 trial, unprotected PBA HatTrick⍭ lost 97% yield to Ascochyta. PBA HatTrick⍭ is now rated moderately susceptible (MS) and will require fungicide under conditions that favour Ascochyta. The good news is that whilst Ascochyta can now cause more damage on unprotected PBA HatTrick⍭, it is just as easy to manage as when PBA HatTrick⍭ was rated MR.
- Phytophthora root rot (soil borne) and Sclerotinia diseases (soil borne and air borne) are considered moderate to high risk in 2020 because although inoculum loads are unlikely to have increased, their survival will have been prolonged by the drought.
- Botrytis seedling disease (BSD, seed borne) is only likely in crops planted with seed produced in the 2016 (and possibly 2017) crop year. In any case proper seed treatment provides 100% control of BSD.
- Botrytis grey mould (BGM, air borne); the BGM fungus is ubiquitous, has a very wide host range and is a good saprophyte - if conditions favour BGM i.e. dense canopies, warm humid weather, it will occur.
- Root lesion nematodes (RLN, *P. thornei* soil borne) can survive dry periods. Recent research has shown it takes a double break of 40 months free of host plants to reduce numbers to a minimum threshold (2/g soil) so it is unlikely the current drought will have reduced RLN numbers if they started high (40/g) which was likely in the 2016 season. Even starting numbers of 10/g still need a break of 30 months https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/how-long-does-it-take-to-reduce-pratylenchus-thornei-populations-in-the-soil.

- Viruses are an unknown threat after a drought. Most need green plants as reservoirs (some are seed borne) and hosts for their vectors. However, as vectors can fly or be blown in from regions that have not experienced drought, viruses are still a risk to 2020 chickpea crops.

Seed quality

Obtaining good quality seed after a drought may be an issue in 2020. In Nov/Dec 2019, we tested seed from as far back as 2016 and whilst germination of all lots exceeded the Pulse Australia (PA) minimum standard of 70%, some lots were slow getting there, indicating possible loss of vigour. All planting seed should be germination tested and if it meets the PA standard, we recommend it be treated and 'test planted' into paddocks intended for chickpeas in 2020, and the number that emerge counted – this is your best indicator of seed and seedling vigour and may assist identify herbicide residues, but should not be relied on as the sole indicator for this, as symptoms of residual herbicides can in some situations be slow to develop. Paddock emergence tests are best done in March/April.

If you are sourcing seed from outside your region e.g. interstate, be sure the variety is suitable for your farming system and have the seed germination and pathogen tested.

Irrespective of age and origin, all planting seed should be treated with a registered seed dressing – these control seed borne Ascochyta (internal and external), seed borne Botrytis (BSD) and protect seedlings from a range of opportunistic soil organisms that can reduce seedling vigour and establishment under less than favourable conditions e.g. cold or wet soils, deep planting. Planting quality, treated seed is your best bet of healthy seedlings – these will have a rapidly growing root system to obtain nutrient and moisture, be more competitive with weeds and less susceptible to disease.

Predicta®B for assessing Ascochyta risk

The value of Predicta®B as an Ascochyta management tool has not been determined because we do not know what the numbers mean in terms of risk or management. Predicta®B results that are positive for Ascochyta on samples collected after the drought should not be surprising give the persistence of inoculum under drought conditions. On the other hand, a negative result does not mean your Ascochyta risk is nil or low as the test is only as good as the sampling method and inoculum can arrive in your paddock after sampling via wind, machinery, vehicle, animals, surface water flows or untreated seed.

Chickpea Ascochyta Research Update: Is efficacy of Aviator Xpro and Veritas reduced by rain after application?

Previous research (2007) at Tamworth using a rainfall simulator showed that efficacy of the fungicides Barrack720® (720g/L chlorothalonil) and Dithane® Rainshield® (750g/kg mancozeb) on chickpea Ascochyta on cultivar Jimbour was not significantly reduced by 50mm rain in 10 minutes. 150mm in 30 minutes also did not reduce efficacy of Barrack720 but did reduce slightly the efficacy of Dithane. Such rainfall intensities are not common in chickpea crops grown in eastern Australia. From these experiments we concluded that plant tissue sprayed with these fungicides would still be largely protected if rain fell after application (new growth after application would not be protected as both products are protectants only). The 2010 chickpea season (that had frequent rain events) supported this conclusion.

The recent registrations of Aviator Xpro® and Veritas® (both in 2018) for chickpea Ascochyta (with restrictions on number of applications and timing – see labels for details) raised the question of how rain fast are these products.

Two experiments were conducted at Tamworth Ag Institute in December 2019 - January 2020 to determine the effect of simulated rain on the efficacy of Aviator Xpro and Veritas on Ascochyta; Unite®720 (720g/L chlorothalonil) and water were the control treatments. The first experiment (4 reps) was with cv Kyabra⊕ and the second (4 reps) with cvs Kyabra⊕ and PBA Seamer⊕.

As the results were the same, we report here the second experiment. Plants were sprayed with water, Unite, Aviator Xpro or Veritas using a backpack sprayer with a 1m boom fitted with 110/015 flat fan nozzles at 50cm spacing and a walking pace of approximately 6kph. The fungicide treatments were allowed to air dry for 2hr when the 'rain' plants were placed in the rainfall simulator and exposed to 50mm over 75 minutes or 100mm over 150min (recorded by two rain gauges at each side of the simulator pad). After removal from the simulator, plants were allowed to air dry for 2h, arranged on racks in replicate boxes (55L plastic with clear lids), inoculated to run off with a cocktail (2,000,000 conidia/mL) of 20 Ascochyta isolates obtained from commercial chickpea crops and the boxes placed in a controlled environment facility operating at 12h/12h day/night 15C/20C. Leaf wetness was maintained with ca 50mm depth water in the base of the boxes and firm fitting lids. After 48h the lids were removed and plants were examined for Ascochyta. Five days after inoculation (DAI) first symptoms (petiole wilting) were evident and at 9 DAI, Ascochyta was assessed by counting the numbers of petioles, leaves and stems with symptoms.

The only plants that developed Ascochyta were those sprayed with water; PBA Seamer⊕ had less disease than Kyabra⊕.

We conclude from this experiment that efficacies of chickpea Ascochyta fungicides Veritas and Aviator Xpro with a 2 hour dry period after spraying and prior to rain occurring, are not affected by simulated rainfall of 50mm in approximately 75min or 100mm in approximately 150min. As such intensities are uncommon during chickpea seasons in areas of Australia where Ascochyta occurs, it is reasonable for growers to be confident that once these fungicides have dried on plant tissues, those tissues will remain protected.

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5 years of Nitrogen research – Have we got the system right?

Richard Daniel, Rachel Norton, Anthony Mitchell, Linda Bailey, Denielle Kilby, Branko Duric and Lawrie Price, Northern Grower Alliance

Key words

nitrogen, efficiency, soil movement, timing

GRDC code

NGA00004

Take home messages

- Over the 14 trials from 2014 to 2017, the efficiency of nitrogen (N) grain recovery from soil N was ~4 times that of fertiliser N that was applied in the year of cropping
- Maintaining high soil N levels is critical for cereal production efficiency due to the poor fertiliser N grain recovery
- Testing of grain, stubble and soil at harvest was able to account for a mean level of ~79% of the applied fertiliser N over 23 comparisons, however in 4 of the 23 comparisons, testing only accounted for 30-50% applied fertiliser N
- The majority of the additional N at harvest was recovered in the soil and averaged ~65% of the applied quantity
- The slow and shallow fertiliser N movement in soil is likely to be impacting on grain recovery efficiency
- Strategies to get fertiliser N deeper, more quickly, may provide useful efficiencies in uptake and reduce potential losses
- Strategies that can improve N contribution from the legume phase will be highly productive
- Fallow N fertiliser applications are likely to provide a benefit over at planting application in years with low in-crop rainfall.

Background

Northern Grower Alliance (NGA) have been heavily involved in nitrogen (N) management trials in wheat since 2012. The focus has always been on methods to improve the efficiency and economics of N nutrition in wheat but the specific focus shifted over time:

1) 2012-2014: Economics and fit of late application
2) 2014-2018: Impact of application method and timing.

In addition to generating answers on the two main themes, a large body of data had been created on N uptake efficiency together with measurements of soil movement and fate of N.

Rather than focusing on individual trial results, this paper focuses on N management 'system implications' and challenges whether we really have got the system right.

Grain nitrogen recovery

Grain N recovery in wheat has been calculated in trials from 14 individual locations conducted during the 2014-2017 seasons. A wide range of production conditions have been experienced with yields ranging from ~1 to 5t/ha. Three steps were taken in calculating the grain N recovery from fertiliser:

1. Grain N recovery for each treatment was calculated as yield (kg/ha) x % protein/100 x 0.175
2. 'Net' grain N recovery was then calculated by deducting the grain N recovery in the untreated (unfertilised treatment)
3. % grain N recovery was calculated by dividing the net recovery by the amount of N applied

Table 1. % grain N recovery from urea applications in 15 trials, 2014-2017

Season	2014		2015		2016		2017	
Method/ timing	All IBS		Drilled in fallow/IBS/ PSPE		Incorporated in fallow/IBS/ PSPE		Spread in fallow x 2/PSPE	
Variety(s)	EGA Gregory⑪		EGA Gregory⑪		Suntop⑪		Lancer⑪, Suntop⑪ & 5 other varieties	
# of trials	4		5		3		3	
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**
Urea 50 kg N/ha	21%	13-34%	30%	<0-45%	23%	16-27%	15%	10-19%
Urea 100 kg N/ha	16%	12-26%	19%	<0-31%	18%	12-23%	9%	7-12%
Urea 200 kg N/ha	9%	5-17%	11%	<0-17%	10%	8-12%	5%	3-6%

NB Data from two trials at Billa Billa 2017 site included. IBS = Incorporated By Sowing, PSPE = Spread Post Sowing Pre Emergent. Recovery data for each urea rate was generated from one application timing in 2014 but 3 timings in all 2015-2017 trials.

Key points

1. As expected, the % grain N recovery reduces as the N application rate increases.
2. Trials were conducted over a range of varieties with no indication of a consistent difference in response to fertiliser N rate between varieties.
3. Most applications were incorporated but some were surface spread and not incorporated.
4. No indication of difference between incorporated versus spread but not incorporated.
5. Recoveries appeared lower in 2017 – low in-crop rain, low yields with reduced N responses.

Grain N recovery from available soil N was also calculated for all trials in 2016 and 2017. Soil N was measured to 120cm at both planting and harvest. (Data from 2014 and 2015 was not included as soil N was only assessed during the fallow for site selection and often to 60cm depth). Two steps were taken in calculating the grain N recovery from soil N:

1. The quantity of soil N 'used' was calculated by the amount in the soil at planting minus the amount at harvest.
2. % grain N recovery was calculated by dividing the untreated grain N recovery by the amount of soil N used.

NB: an estimate of the quantity of N mineralised during the cropping season was not included for any calculation but was assumed to be consistent for all treatments. Inclusion of an estimate of mineralised N would lower the % grain recovery for both soil and fertiliser but is unlikely to change the relative differences.

Table 2. % grain N recovery from soil only, fertiliser only or combined soil and fertiliser application in 6 trials 2016-2017

Season	2016		2017	
Number of trials	3		3	
N 'source'	Mean	Range	Mean	Range
Soil only	98%	73-112%	62%	55-70%
Fertiliser only	23%	16-27%	15%	10-19%
Soil & fertiliser	62%	54-74%	40%	33-46%

NB: The mean and range used for 'fertiliser only' is for the most efficient rate (50 kg N/ha) from Table 1.

Key points

1. The % grain N recovery when calculated on combined soil and fertiliser quantities is in line with industry convention (~40-60% N efficiency depending on year).
2. However, **each kg of soil N was ~4 times more efficient** (range 3-6 times) in producing yield and protein than each kg of fertiliser N – even when fertiliser was applied at the most efficient rate.

Situations of concern

N fertiliser recommendations are generally based on setting a target for yield and protein and then ensuring a quantity of soil and fertiliser N that is generally double that target (i.e. working on a 40-60% grain N recovery efficiency). This approach is generally effective, but on the basis of these results, will struggle when soil N levels become low. Common examples would be:

- Soil N levels are heavily depleted following an unexpectedly very high yielding crop (e.g. in 2012); and
- Following a very dry fallow where mineralisation is greatly reduced.

In these situations, N fertiliser application rates may need to be increased to commercially impractical and uneconomic levels to achieve the expected outcome. In some situations with very low starting N quantities, a change from cereal to a legume may be a much better option.

Why is the fertiliser efficiency so low in the year of cropping?

Movement of N

One possible reason for the low observed efficiency of grain N recovery from fertiliser applied in the year of cropping may be the amount and speed of N movement in soil. During 2015-2017 a primary objective has been to evaluate the impact of N application into a dry soil profile during the fallow. The hypothesis was that the applied N would move further with fallow rain events so that N would be deeper and more uniformly distributed by planting.

Figures 1 and 2 are indicative of the results achieved following N application during the fallow in 2015/16 and 2016/17.

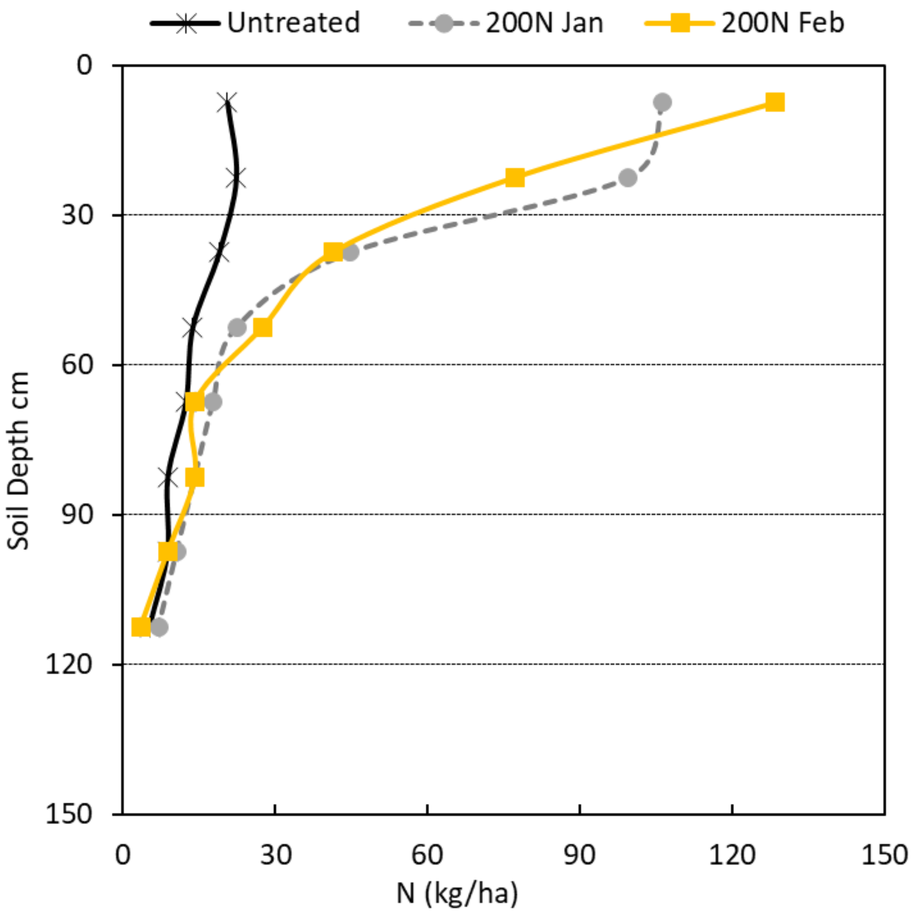

Figure 1. Soil distribution of N at Mullaley at planting (May 2017) following application of urea in January or February 2017. 175mm of rain was recorded between the January application and planting. 140mm of rain was recorded between the February application and planting.
(NB: Both N applications were spread and not incorporated. Sampling method - 6 individual 0-120cm depth cores taken per plot. Samples from each depth were bulked with a single sub sample taken for analysis. Not replicated.)

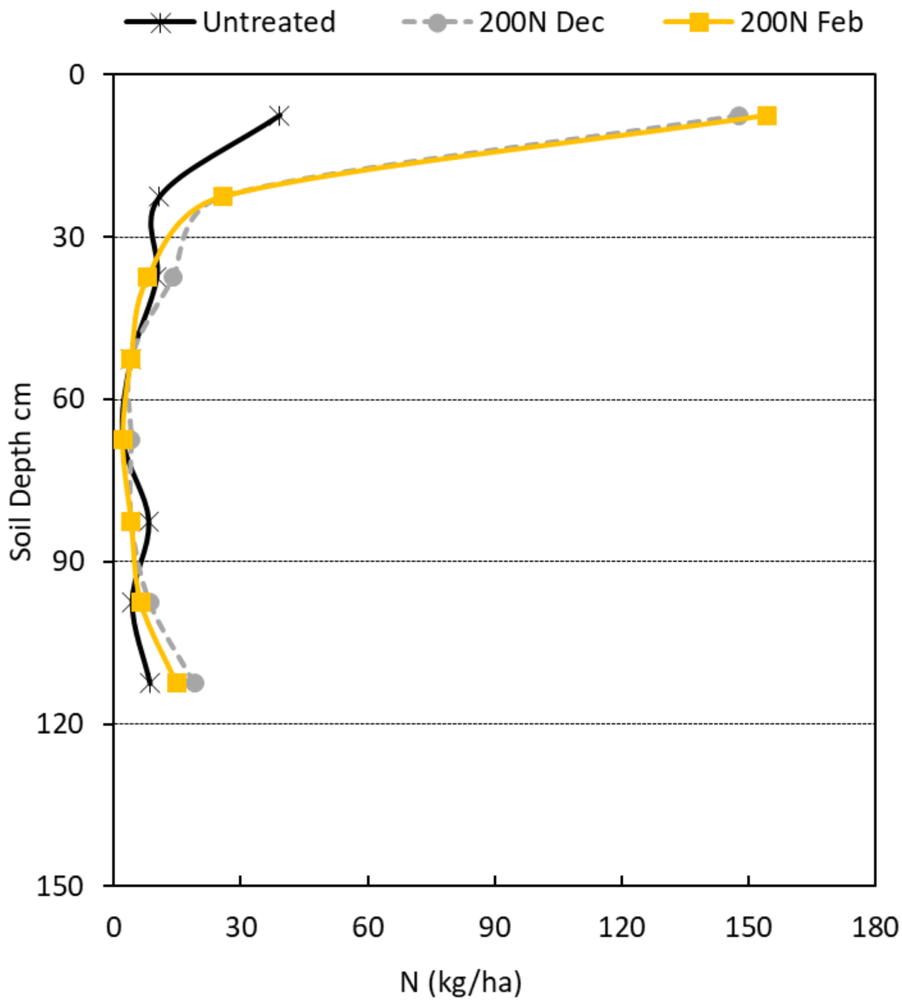

Figure 2. Soil distribution of N at Tulloona at planting (June 2016) following application of urea in December 2015 or February 2016. 225mm of rain was recorded between the December application (spread and incorporated) and planting. 65mm of rain was recorded between the February application (spread and not incorporated) and planting.
(NB: Sampling method - 6 individual 0-120cm depth cores taken per plot. Samples from each depth were bulked with a single sub sample taken for analysis. Not replicated.)

Key points

1. Even in a dry soil profile, the movement of N in these trials (predominantly vertosol soil types) was slower and shallower than expected.
2. The majority of N applied in fallow (either surface spread or incorporated to depths of ~3-5cm) was still in the 0-15cm soil segment at planting.
3. Sampling in smaller increments e.g. 5cm may reveal clearer differences in movement between application timings.

Implications of reduced N movement

The slower observed movement of N in soil may explain why in 10 of the 11 application timing trials there has not been a significant advantage from fallow N application compared to N applied at planting - as long as there were reasonable levels of in-crop rain. The 2017 season was however characterised by useful fallow rains (particularly in March) but with very low levels of in-crop rain (particularly June-September).

Billa Billa 2017

The site at Billa Billa in 2017 was the first to show a significant benefit from both fallow N applications compared to the same quantity applied at planting (or in-crop).

Figure 3 shows the distribution of soil N at planting from fallow application with the majority of N in the 0-15cm depth for both December and March 2017 applications, but with apparent increased movement from the December application. This site had the deepest movement of N recorded in any of the trials in 2016 or 2017.

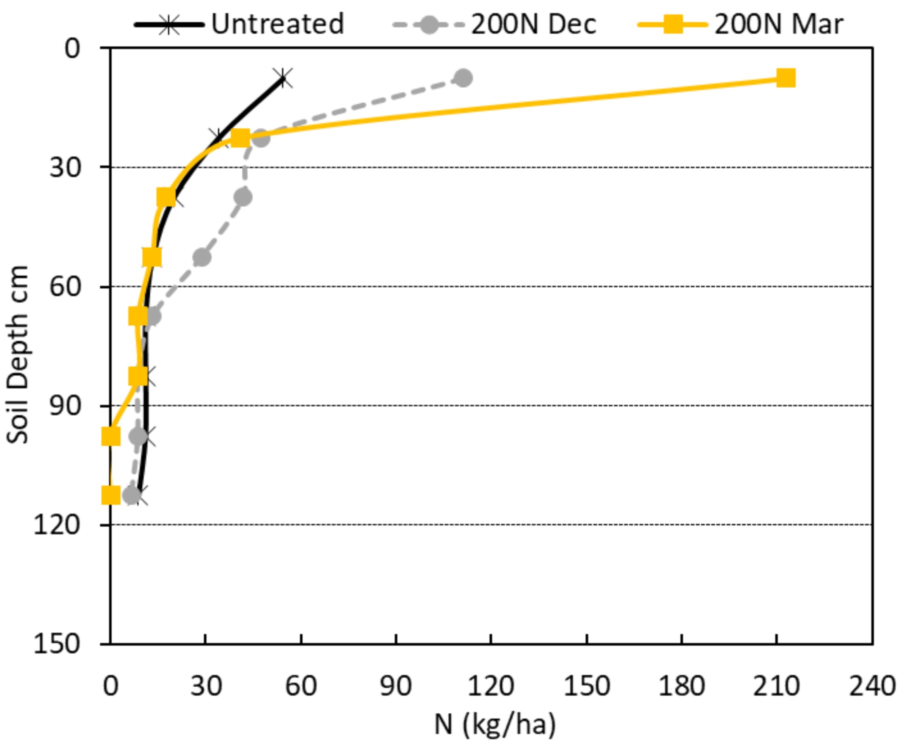

Figure 3. Soil distribution of N at Billa Billa at planting (May 2017) following application of urea in December 2016 or March 2017. 279mm of rain was recorded between the December application and planting. 154mm of rain was recorded between the March application and planting.
(NB: Both applications spread and not incorporated. Sampling method - 6 individual 0-120cm depth cores taken per plot. Samples from each depth were bulked with a single sub sample taken for analysis. Not replicated.)

Figure 4 shows the yield results (variety Lancer⦶) at this site. There was no significant N response from fertiliser applied at planting (or in-crop) at this site, with only 71mm of in-crop rain received between planting and the end of September. However applications in December or March provided a significant increase in both yield and protein (not presented).

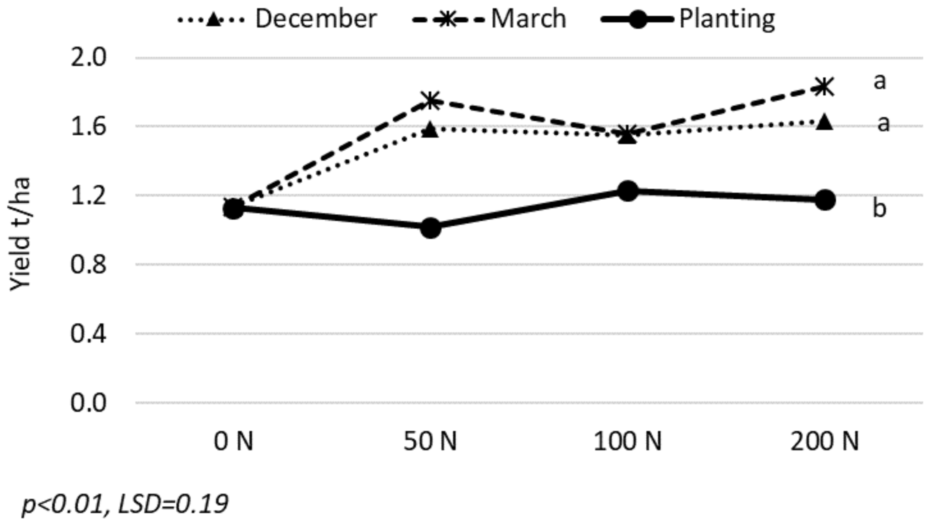

Figure 4. Effect of application timing and N rate on yield, Billa Billa 2017
(Treatments that share the same letter are not significantly different at P=0.05. All N rates were spread only)

Table 3 shows the distribution of N (in excess of untreated levels) by soil depth at harvest and the quantities of rainfall recorded between application and planting or harvest.

Table 3. Depth distribution of soil N at harvest (in excess of untreated levels) from 200 kg N/ha applications, Billa Billa November 2017

	December spread	March spread	Planting PSPE	In-crop Spread
Rainfall - application to planting	279mm	154mm	-	-
Rainfall - application to harvest	465mm	340mm	186mm	160mm
Soil depth	**Additional soil N kg/ha v untreated at harvest**			
0-15cm	32	70	36	82
15-30cm	48	48	4	2
30-45cm	35	11	4	4
45-60cm	20	7	4	4

NB There was no indication of any movement of fertiliser applied N deeper than 60cm. Soil recovery from PSPE application was very low with only 1mm of rain recorded 4 days after application, followed by 9mm at 37-38 days after application.

Key points

1. Although the majority of N from December or March application was still in the 0-15cm zone at planting (Figure 3), the yield and protein results indicate it had moved deep enough to be available to the crop in a season with very low in-crop rainfall.
2. Increased benefit from fallow N application compared to application at planting are likely in situations with good levels of fallow rainfall but followed by low levels of in-crop rainfall.
3. The majority of excess N applied in December was recovered in the top 45cm at harvest after a total of 465mm of rainfall.
4. The majority of N applied in March was recovered in the top 30cm at harvest after a total of 340mm of rainfall.

NB Soil recovery from the PSPE application was very low in this trial with the first useful rainfall (9mm) 37 days after application. Unfortunately soil sampling was not planned/conducted in plots where N was incorporated by sowing for comparison.

How much nitrogen was actually recovered at harvest?

Assessment of the fertiliser N fate (in grain, soil and stubble) was conducted in 2015, 2016 and 2017 but with no attempt to estimate the residual N in the root system. Table 4 shows the mean quantities of N, in excess of the level where no fertiliser N was added. In 2015, results were only assessed for 200 kg N/ha applied and incorporated by sowing. Results in 2016 and 2017 are a mean of 4 application timings. In 2016, 3 of the 4 applications were spread and not incorporated with all applications spread and not incorporated in 2017.

Table 4. Mean levels of N (kg N/ha) in grain, stubble and soil samples at harvest following application of 200 kg N/ha, in excess of untreated levels, 8 trials 2015-2017

Season	2015		2016		2017	
Number of trials	3		3		2	
	Mean	Range	Mean	Range	Mean	Range
Grain	0	-16-21	20	5-39	8	3-13
Stubble	17	6-48	17	3-43	8	1-26
Soil	79	58-102	136	50-221	128	54-234
Total	**96**	**85-134**	**174**	**66-263**	**143**	**60-258**

Key points

1. Over 23 individual application timing comparisons, ~79% of the applied rate was recovered between grain, stubble and soil.
2. On average ~21% of the applied N was not able to be accounted for in grain, stubble or soil.
3. The majority of additional N was recovered in the soil and on average accounted for 65% of the applied N.
4. In 18 of 23 comparisons, testing accounted for more than 60% of the applied N.
5. The lowest recoveries were from 2 sites in 2015 where N was incorporated by sowing – both 40-50%, one site in 2016 from spreading on wet soil at GS30 – 30-40% and one in 2017 from application PSPE – 30-40%.
6. Grain recovery is likely to be the most accurate measure with stubble and soil more variable due to issues such as sampling and uniformity of spreading.

Was nitrogen still available for the following crop?

Two of the trial sites from 2016 (Tulloona and Macalister) were planted to winter crop in 2017 and were monitored for response and benefits in the 'year 2' crop. Table 5 shows the soil test results taken at planting and harvest in year 2.

Table 5. Soil N levels (kg N/ha) at Tulloona and Macalister following application of N at different rates applied at wheat planting in 2016

	Tulloona		Macalister	
N rate at sowing in 2016	April 2017	Oct 2017	Aug 2017	Dec 2017
Untreated	53 b	29 b	78 c	44 b
50 kg N/ha IBS	76 b	32 b	99 bc	46 b
100 kg N/ha IBS	71 b	21 b	131 b	80 b
200 kg N/ha IBS	162 a	122 a	237 a	178 a
P value	*<.01*	*.04*	*<.01*	*<.01*
LSD	*33*	*75*	*39*	*62*

NB Sampling method - 4 individual 0-120cm depth cores taken per plot. Samples were separated into 0-30 and 30-90cm intervals with each depth bulked and a single sub sample taken for analysis. 4 replicates sampled in each treatment

Key points

1. The large LSD figures (least significant differences) highlight the variability that can occur with soil testing and that the number of soil samples collected should have been larger to account for this.
2. While acknowledging the above, soil testing ~12 months after N application (April and August 2017) showed significantly increased soil N levels in the 200 kg N/ha treatments (109-159 kg N/ha additional compared to untreated).
3. Differences were less clear from the 50-100 kg N/ha rates applied in 2016.
4. The lowest soil N levels at planting in 2017 were from the untreated samples.
5. At harvest of the year 2 crops, there was still an additional ~90-130 kg N/ha of soil N in plots that had received 200 kg N/ha in 2016.

NB At the Tulloona site, ~60 % of the additional soil N was still found in the top 45cm with 45% found between 15 and 45cm. At the Macalister site, ~49 % of the additional soil N was still found in the top 45cm with 31% found between 15 and 45cm.

The Tulloona site was commercially planted to chickpeas and the Macalister site was planted to wheat. At Tulloona, at the end of September it was visually apparent that all plots that had received the 200 kg N/ha rate in year 1 were 'greener' than the remaining plots and the trial warranted harvest. Previous wheat results had indicated the most consistent N response was in grain protein, so yield and grain quality were assessed at both sites. Figures 5 and 6 show the yield and protein responses in year 2.

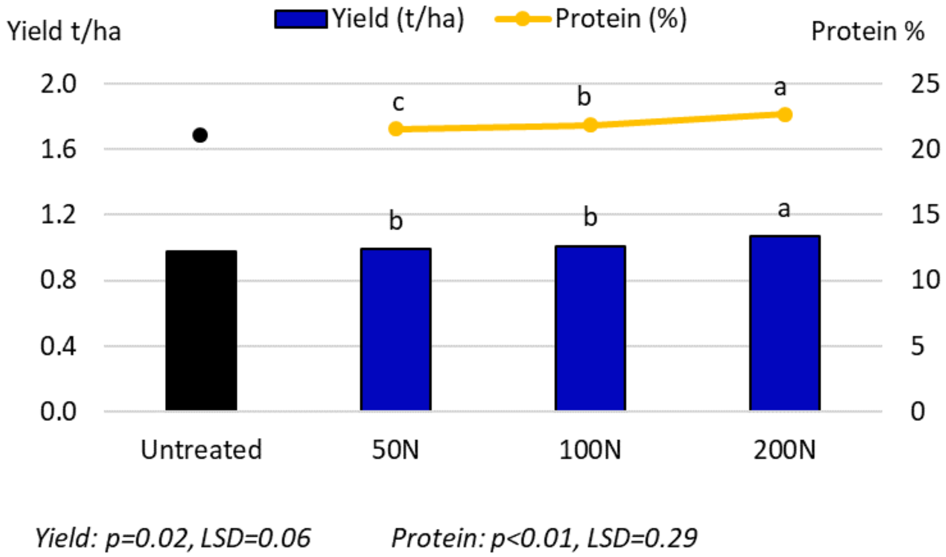

Figure 5. 2nd year impact of N rate - chickpeas, Tulloona 2017
(Treatments that share the same letter, within an assessment, are not significantly different at P=0.05. Results for each N rate are from a factorial of 3 timings x 2 varieties. Untreated not analysed and included for comparison only)

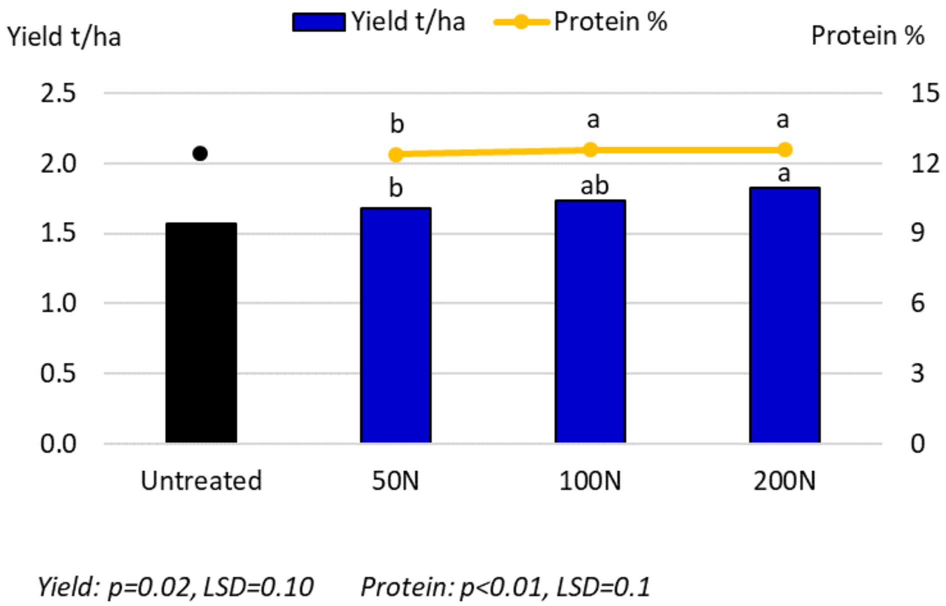

Figure 6. 2nd year impact of N rate - wheat, Macalister 2017
(Treatments that share the same letter, within an assessment, are not significantly different at P=0.05. Results for each N rate are from a factorial of 3 timings x 2 varieties. Untreated not analysed and included for comparison only)

Key points

1. Significant increases in both yield and grain protein were recorded in year 2 from the 200 kg N/ha rates applied in 2016 compared to the 50 kg N/ha rate at both sites.
2. Although soil testing did not show a significant difference in soil N between the 50 and 100 kg N/ha rates, there was a significant increase in grain protein recorded in both crops from the 100 kg N/ha treatments compared to the 50 kg N/ha rate.

Economic impact

Tulloona

- Wheat 2016: all nitrogen rates achieved at least break even in 2016 due to yield benefits (0.7-1.2t/ha) combined with increased grain quality in a ~4t/ha yielding situation
- Chickpeas 2017: although grain protein was increased by all rates of N applied in 2016, only the 200 kg N/ha rate resulted in a significant yield increase. This equated to an extra $60/ha net benefit
- Soil testing indicates an extra 90 kg N/ha is still available to benefit year 3 cropping from the 200kg N/ha applications.

Macalister

- Wheat 2016: there was no yield impact from applied N but increases in protein of ~2-3%. There was no net benefit with mean yields ~2.0-2.5t/ha
- Wheat 2017: significant yield increases were recorded from all 2016 rates compared to the untreated (0.1-0.25t/ha). Despite significantly increased protein from the 100 and 200 kg N/ha rates, all grain was H2 quality. Net benefits of $32-$73/ha were achieved in year 2
- The 50 kg N/ha rate was the only one to achieve a net benefit over the 2 years of ~$20/ha
- Soil testing indicates an extra 130 kg N/ha is still available to benefit year 3 cropping from the 200 kg N/ha applications.

Conclusions

This series of trials over 4 cropping seasons and 14 trial locations has provided results that question some of our current management practices.

- It has supported the general N grain recovery ‘rule’ applied in N budgeting of 40-60% of available soil and fertiliser N but highlighted a large difference in efficiency between the two sources
- It has highlighted the poor efficiency of fertiliser N grain recovery in the year of application with mean levels of ~15-20% applied N recovered in grain at common commercial rates (50 -100 kg N/ha)
- The relatively shallow and slow movement of the applied N is likely to be a major cause for this inefficiency
- Consider non-cereal options in paddocks with very low soil N levels
- Testing at harvest of grain, stubble and soil indicated nearly 80% of the applied N could be accounted for, although in a small number of situations this level dropped to as low as 30-50%
- There was no clear pattern of difference between urea surface spread or spread and shallow incorporated in terms of N recovery. They were both equally good (or bad)
- Initial assessment of response in 2nd year crops was encouraging with ~50% of the initial 200 kg N/ha rate still available for crop response in year 3
- At one of the two sites monitored in year 2, all of the net benefit from fertiliser occurred in year 2
- The errors associated with soil testing (e.g. core number, uniformity of sample mixing and sub sampling) make ‘precise’ recommendations on fertiliser N levels difficult.

Key industry challenges

- Ensure soil N levels do not continue to decline as the required levels of fertiliser N in the year of cropping would rapidly become uneconomic and impractical and cereal production less efficient
- We need to identify methods to get fertiliser N deeper in the profile, more quickly, to improve availability and efficiency

- Identify and if possible, manage the unaccounted losses from fertiliser N application.

Where to next?

The results from this work indicate we still have much to learn, or at least to refine, with the management of our most important and best understood nutrient for cereal production. Any practices that can improve the efficiency of N accumulation from the legume phase are going to be exceedingly valuable, together with methods to increase the efficiency of fertiliser N use in the year of cropping.

Acknowledgements

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⌽ Varieties displaying this symbol beside them are protected under the Plant Breeders Rights Act 1994

Fixing more N by improving inoculant performance in sub-optimal conditions

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Key words

rhizobia, nodulation, lentil, field pea, vetch, faba bean

GRDC code

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Take home messages

- Rhizobia strains selected from soils with pH similar to those encountered across large areas of central and southern NSW have increased nodulation in lentil, field pea and vetch compared to the current Group F strain
- > 40% of paddocks surveyed in the GRDC northern region covering central and southern NSW had a pH_{Ca} < 5.0
- While acid tolerant rhizobia may improve nodulation in acidic soils, consideration to amelioration acidity should be given where pHCa <5.0 as nodulation is likely to still be inadequate at this pH.

Background

There are three key considerations in achieving successful nodulation of legumes. Firstly, the host plant needs to be suited to the conditions in which it is grown. Secondly, there needs to be a sufficient number of a compatible strain of rhizobia for the host plant. Thirdly, there needs to be capacity for communication (signalling) between the host plant and the rhizobia for root infection and nodulation to occur. Suboptimal conditions including soil acidity, aridity, low clay content of soil, inadequate nutrient availability (for the host plant and the rhizobia) and/or the presence of herbicide residues can impact the host plant, the rhizobia and/or the interaction of plant and rhizobia thus reducing the formation of an effective symbiosis and reducing potential nitrogen fixation. Nodulation and nitrogen fixation are not a given when growing legumes. Legumes that don't form an effective symbiosis use nitrogen (N) from the soil pool rather than contributing to building soil N.

So what is the current situation and probable impediments to achieving higher nitrogen fixation in legumes and what options are there to improve the situation? In the remainder of this paper we will discuss current research underway to deliver more resilient rhizobia strains for lentil, faba bean, field pea and vetch to the marketplace along with other facets of management that need to be considered to improve legume performance.

The search for more resilient, robust rhizobia strains

Current recommendations suggest lentil and faba bean are inoculated with Group F (containing the rhizobia strain WSM1455) while field pea and vetch are inoculated with Group E (SU303). However, the current Group E is difficult to manufacture and as a result, field pea and vetch are in fact inoculated with Group F inoculant. Fortunately, the current rhizobia strain (WSM1455) used in Group F inoculant has good compatibility across all of these host legumes. However, the current Group F which was isolated from soil in Greece (pH_{Ca} 8.0) and released in 2002, exhibits a rapid decline in capacity to nodulate plants where pH_{Ca} < 6.0, with plants generally inadequately nodulated where pH_{Ca} <5.0 (Yates et al. 2016; Ballard et al. 2019).

Large areas of cropping land in central and southern NSW have soils where the capacity of the current Group F to effectively nodulate host plants is restricted. A recent survey of 150 commercial paddocks in the GRDC northern region found that soil pH in the top 20 cm of the soil profile would likely restrict the performance of the current Group F in ≥ 40% of paddocks sampled (Table 1). Rhizobia with greater acid soil tolerance would likely increase capacity for nitrogen fixation throughout the regions sampled in this survey.

Table 1. The average soil pHCa of 150 commercial paddocks in the central east, central west, south east or south west regions of the GRDC northern region as sampled in 2019 and the percentage of paddocks where soil pH was less than 5.0.

Depth	**Average soil pH_{Ca}**	**Percentage of paddocks pH_{Ca}<5.0**
0-5 cm	5.3	39
5-10 cm	5.0	84
10-20 cm	5.6	40
20-30 cm	6.1	15

Both Murdoch University (Centre for Rhizobium Studies) and SARDI have been isolating rhizobia suitable for consideration as a Group F replacement from acidic soils (pH_{Ca} 4.5-5.5); Murdoch University accessions have been sourced from Italy and SARDI accessions from commercial paddocks in South Australia. Preliminary glasshouse and field studies in Western Australia identified two acid-tolerant Italian strains (WSM1455, WSM4643) which produced improved nodulation, nitrogen fixation and grain yield in field pea (Yates et al. 2017). Similar studies in South Australia reported improved performance in lentil and faba bean where acid tolerant Australian strains (SRDI969, SRDI970) were used compared to the current Group F (WSM1455) strain (Ballard et al. 2019). These results are encouraging. However, to be considered for commercial release, it is important that any potential strain has capacity to improve nodulation across the entire Group F host range which also includes vetch. In addition, any elite strain has to be able to be manufactured easily and to remain stable up until the point of use at sowing.

In 2019, field testing of the four elite acid-tolerant strains commenced in the Northern GRDC region with sites sown at Griffith, Condobolin and Canowindra. The objective of the three sites was to evaluate the performance of the elite strains in differing soils (Table 2) and under varying climatic conditions. Griffith was the most challenging of the sites due to lower soil pH, low clay content and high summer temperatures. Canowindra with a higher soil pH, higher clay content and lower temperatures potentially increased survival capacity of the rhizobia, although such conditions also increase the potential for higher background rhizobia levels that compete with introduced strains.

Table 2. The location, soil pH and texture of three sites used for evaluation of elite rhizobia strains for lentil, faba bean, field pea and vetch in the GRDC Northern Region in 2019.

Location	Soil pH_{Ca} (0-10 cm)	Soil texture
Griffith	4.6	Light sandy loam
Condobolin	4.8	Sandy loam (red chromosol)
Canowindra	5.1	Loam (dermosol)

For lentils, there was a significant difference in nodulation across sites and due to rhizobia strain (Figure 1). The most acidic site, Griffith, had lower nodulation than all other sites and only WSM4643 produced a significantly higher nodulation score than the current Group F strain. At Condobolin and Canowindra, both WSM1483 and WSM4643 produced significantly higher nodulation scores than the current Group F, while SRDI969 was also significantly higher than the current Group F at Canowindra. None of the strains at any site gave an overall nodulation score that is considered adequate (score ≥ 4; Yates et al. 2016).

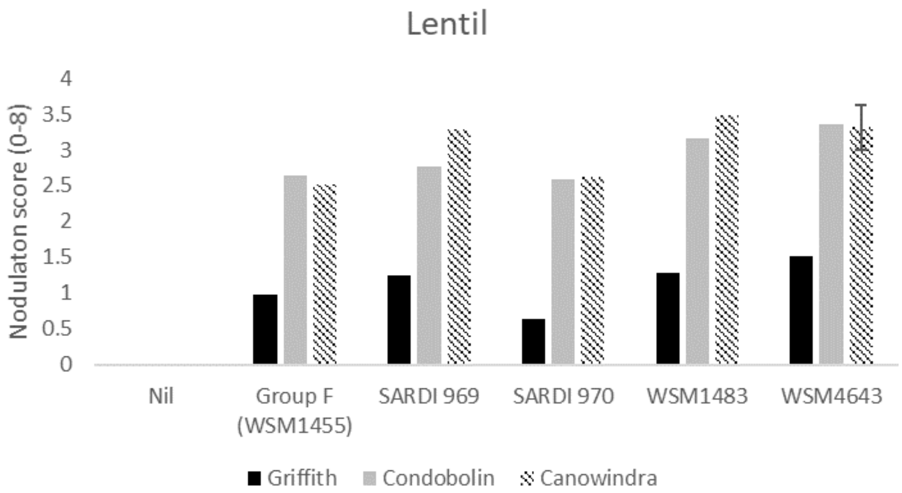

Figure 1. The average nodulation score of 15 lentil plants at Griffith, Condobolin and Canowindra where seed was inoculated with peat slurry containing a no rhizobia (nil), the current Group F strain, or one of four experimental strains. A score of 4 is considered adequate under the system developed by Yates et al. (2016).

For field pea, all experimental strains produced significantly greater nodulation than the current Group F at Griffith (Figure 2). At Condobolin and Canowindra, WSM4643 produced significantly higher nodulation score than the current Group F, with WSM1483 also significantly higher at Condobolin.

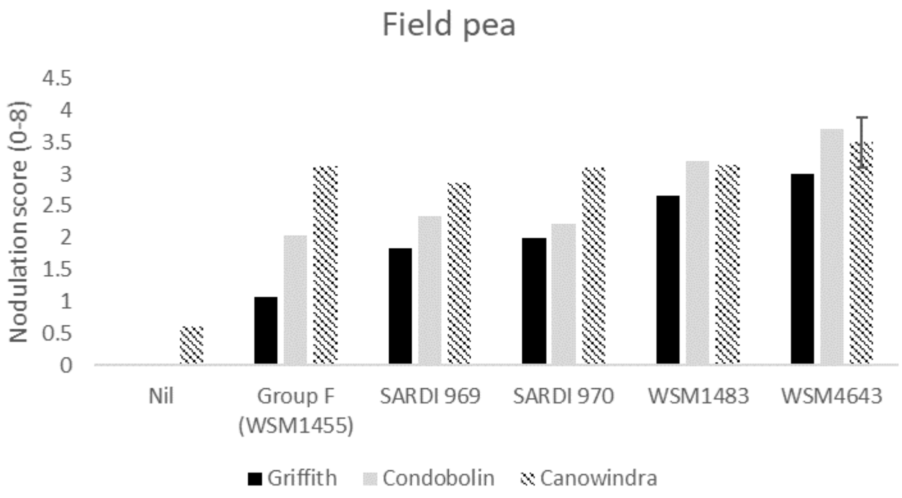

Figure 2. The average nodulation score of 15 field pea plants at Griffith, Condobolin and Canowindra where seed was inoculated with peat slurry containing a no rhizobia (nil), the current Group F strain, or one of four experimental strains. A score of 4 is considered adequate under the system developed by Yates et al. (2016).

For vetch, WSM1483 and WSM4643 produced significantly higher nodulation than the current Group F at Griffith and Condobolin (Figure 3). None of the experimental strains produced significantly higher nodulation than the current Group F at Canowindra. SRDI970 showed poor compatibility with vetch at Condobolin and Canowindra producing very low nodulation scores. It is critical that strains considered for potential release showed strong compatibility across the potential host range.

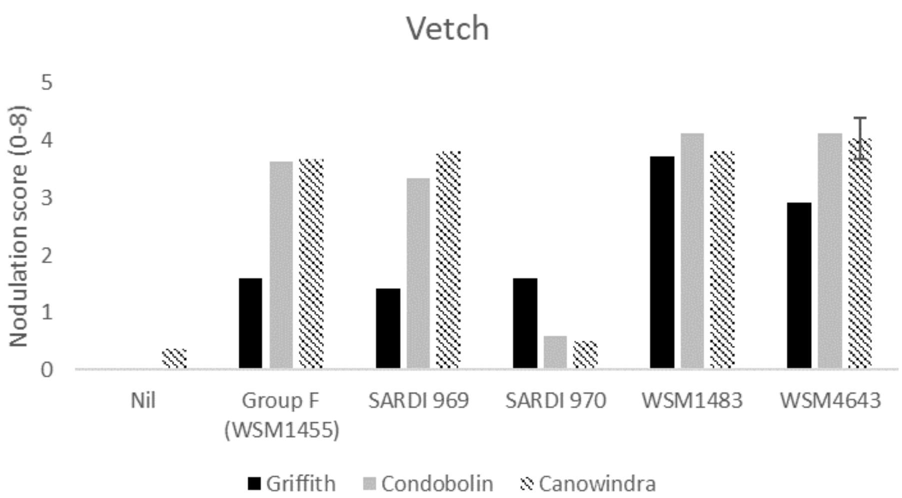

Figure 3. The average nodulation score of 15 vetch plants at Griffith, Condobolin and Canowindra where seed was inoculated with peat slurry containing a no rhizobia (nil), the current Group F strain, or one of four experimental strains. A score of 4 is considered adequate under the system developed by Yates et al. (2016).

Faba beans were grown only at Canowindra and there were no experimental strains that gave nodulation scores greater than those achieved by the current Group F strain (Figure 4).

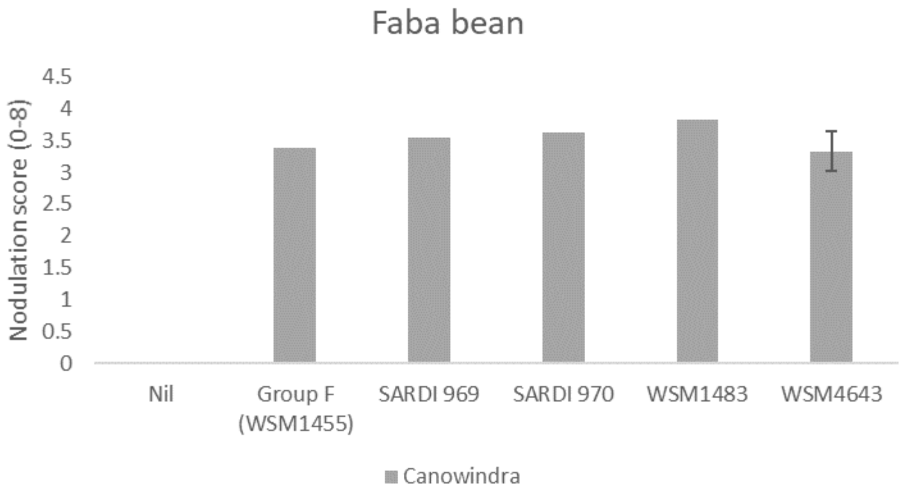

Figure 4. The average nodulation score of 15 faba bean plants at Canowindra where seed was inoculated with peat slurry containing a no rhizobia (nil), the current Group F strain, or one of four experimental strains. A score of 4 is considered adequate under the system developed by Yates et al. (2016).

Samples were collected to determine nitrogen fixation and these are still undergoing processing as are samples collected to determine grain yield. However, based on results to date, it would appear that strains WSM1483 and WSM4643 offer considerable potential to increase nodulation in acidic soils and also have good compatibility with the potential host range. Research is ongoing within the Australian Inoculant Research Group to determine the manufacturability and stability characteristics of the elite strains, as this is a critical consideration in the practical delivery of elite strains to the marketplace.

Are elite strains the answer to increasing pulse production and adaptation?

The development of elite rhizobial strains is an important step forward in increasing pulse production, but it is not a silver bullet. Certainly, pulse production in central and southern NSW is likely to be constrained by acidic soils which are widespread throughout the region and our results indicate that elite strains may increase nodulation in these circumstances. The current strain of Group F was isolated from soils with a pH much higher than that encountered through much of the target growing regions of central and southern NSW and therefore strains selected from soils more comparable in pH are likely to have production and survival advantages. However, our results also show differences in host plant tolerance to soil acidity, with lentil nodulation still well below the level considered adequate even with acid tolerant rhizobia. Thus, soil acidity is potentially impacting the host plant and/or the formation of an effective symbiosis. So are tolerant host plants the answer? Potentially they are also a tool to improve adaptation and production of pulses in acid soil regions. However, what must be considered is that if the acid soil problem is not addressed, it will continue to worsen. The results of our soil survey show that a large percentage of commercial paddocks have soil pH_{Ca}<5.0. Acid tolerant rhizobia and acid tolerant host plants can only do so much and certainly once soil pH falls below 5.0, other problems come into play including reductions in the efficiency of use of applied nutrients. Also, the impact of herbicide residues needs to be considered as these can impact the host plant, rhizobia and the host plant-rhizobia symbiosis. This project is in its early stages and further evaluation is required through time and across sites to determine the impact that elite rhizobial strains may have on potential pulse production.

References

Ballard R, Farquharson E, Ryder M, Denton M, Rathjen J, Henry F, Brand J, Whitworth R, Haskins B, Seymour M, Yates R (2019) Fixing more N – improving the performance of rhizobial inoculants in suboptimal conditions. GRDC Updates. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2019/02/fixing-more-n-improving-the-performance-of-rhizobial-inoculants-in-suboptimal-conditions

Yates, RJ, Abadidoo, Howieson, JG (2016) Field experiments with rhizobia. In. Working With Rhizobia (Eds. JG Howieson, MD Dilworth). Australian Centre for International Agricultural Research and Centre for Rhizobium Studies Murdoch University.

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. The authors also wish to acknowledge the financial and in-kind contributions of Local Land Services and Central West Farming Systems towards the soil survey results presented in this paper.

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What N is in profile - 3 dry years with minimal mineralisation. What are the results showing? Also, insights from a long-term nutrition site running since 2007 in CNSW

Jim Laycock, Incitec Pivot Fertilisers

Key words

nitrogen, mineralisation, grain nitrogen yield, urea

Take home messages

- Segment deep N's in 2020 at 0-30, 30-60cm depths to see where the nitrogen is in the profile
- Don't plant wheat on wheat chasing 2018/19 fertiliser due to potential crown rot infection
- Sustainable continuous cropping systems should include a pulse crop at least twice in a 9-year rotation

Incitec Pivot Fertiliser's long term nitrogen by phosphorus trial was established to describe the cumulative effect of 5 different rates of nitrogen fertiliser and 5 different rates of phosphorus fertiliser on grain yield and protein % in a controlled traffic cropping rotation.

This site was commenced in 2007 with soil N to 0-60cm of 160 kg/N/ha sampled pre plant in 2007 (field peas 2006) and a site Colwell phosphorus of 26 mg/kg. There are 25 fertiliser treatments replicated 4 times and the crop rotation is sown over the same plots annually.

One issue seen in 2019 as a result of accurately sowing row-on-row with sub 2cm Real-Time Kinematic (RTK) auto steer, was high levels of crown rot as a result of sowing on exactly the same plant line as last year's Gregory⚐ wheat. One of the strategies to reduce the impact of carry over crown rot infection is avoiding contact with last season's wheat stubble. When sowing row-on-row, contact with last season's stubble was maximised and crown rot infection levels were high, and screenings were >15%.

Rotation

2007 – Wheat

2008 – Wheat

2009 – Wheat

2010 – Albus Lupins

2011 – Wheat

2012 – Canola

2013 – Wheat

2014 – Canola – resown

2015 – Wheat

2016 – Wheat

2017 – Canola

2018 – Wheat

2019 – Wheat

Seeding and harvest

A small plot cone seeder with 17.5cm row spacing was used in 2007 – 2009 and 25cm row spacing from 2010. From 2010 sowing, trial site management, harvest, data analysis and trial reports were conducted by Kalyx. From 2015 Kaylx plot seeder used sub 2cm RTK, 6 rows at 23cm row spacing, 1.38m wide plots and 10m plot lengths. Harvest grain yield per hectare was calculated on 2m plot centres.

In 2015 the original 20m long plots were cut in half. From 2015, the 2007 'A trial' N and P rates were retained on the western half and the 2015 'B trial' N and P rates were applied on the eastern half of the original plots. See table 1. The 'A trial' treatments continue to build soil P and N while 'B trial' treatments now run down and also build P and N.

Table 1. Treatment list

2007 – 2019 'A trial' P&N kgs/ha treatments	2015 – 2019 'B trial' P&N kgs/ha treatments
40P 0N	0P 0N
40P 120N	0P 30N
40P 90N	0P 60N
40P 60N	0P 90N
40P 30N	0P 120N
30P 0N	10P 0N
30P 120N	10P 30N
30P 90N	10P 60N
30P 60N	10P 90N
30P 30N	10P 120N
20P 0N	20P 0N
20P 120N	20P 30N
20P 90N	20P 60N
20P 60N	20P 90N
20P 30N	20P 120N
10P 0N	30P 0N
10P 120N	30P 30N
10P 90N	30P 60N
10P 60N	30P 90N
10P 30N	30P 120N
0P 0N	40P 0N
0P 120N	40P 30N
0P 90N	40P 60N
0P 60N	40P 90N
0P 30N	40P 120N

Nutrient placement

Triple Super (20% P) was banded with the seed, 50% of the urea (46% N) rate applied at planting banded below and to the side of the seed up until 2014. From 2015 urea is now placed 5cm directly below the seed with the Kaylx plot seeder.

The balance of urea is applied as urea broadcast in wheat at GS31 and at the pre rosette stage in canola. Urea was not applied in 2010 (Albus lupins) and urea was not top-dressed in 2007, 2014 (low yield potential due to replant) and 2018 (dry conditions).

Sulphur has been applied 4 times during the life of the trial as broadcast gypsum (2), banded potassium sulphate (1) and broadcast Gran-Am® (2017). A total of 5kgs/ha of zinc and 2kgs of boron have also been applied.

Urea nitrogen balance at the Grenfell long term NxP trial site

In the absence of deep N testing results for the 2020 season due to the difficulties coring dry soil profiles the annual application of urea nitrogen (kgs/N/ha) and the annual export of grain nitrogen as kgs/N/ha over the current life of the trial from selected treatments is presented in table 2. The method used to balance nitrogen at this site does not consider gains from mineralisation, losses from denitrification, leaching or volatilisation.

Nitrogen mineralised from the soil organic matter and crop residues makes a substantial contribution (~50%) to crop N uptake (Angus and Grace, 2017; Gupta, 2016).

The supply of N from mineralisation is driven by soil moisture, soil temperature and soil organic matter levels. Soil pH also has an effect with slower mineralisation rates on acid soils. Mineralised nitrogen is available throughout the year. Generally, there is more N mineralised and available in autumn and spring and lower availability in winter when soils are at lower temperatures. Whenever there is a rainfall event and surface soil is moist, there is potential for a mineralisation event to occur. Although rainfall events have been few and far between in the past three seasons some nitrogen would still have come into the system.

Potential loss of soil nitrogen through denitrification has been minimal as a result of low rainfall and no waterlogging events. The last potential denitrification events at the Grenfell trial site occurred in 2010 and 2016 (see rainfall figure 1). Nitrate leaching isn't a significant pathway for loss on these soils. (Smith, 2000).

Although volatilisation losses are low on these acid soils during winter, the top dress urea is managed to avoid any loss by topdressing in front of a rainfall event.

Immobilisation of N may occur when plant residues of low N content are decomposing in the soil. Immobilisation represents a temporary unavailability of mineral N in the soil for growing plants to access. Immobilisation was first seen on site in 2015 when wheat on low nitrogen treatments exhibited nitrogen deficiency symptoms where canola residue lay on the soil surface. The residue was concentrated as a chaff pile where the small plot harvester had stopped at the end of each plot.

Grenfell long term NxP trial results

Trial treatments include four rates of nitrogen to supply a total of 30, 60, 90, or 120 kg of nitrogen per hectare annually (unless otherwise indicated). Displayed in figure 2 and table 2 is the total nitrogen supplied as urea for treatments 20P 60N and 20P 120N from the first planting in 2007 and the grain nitrogen removal

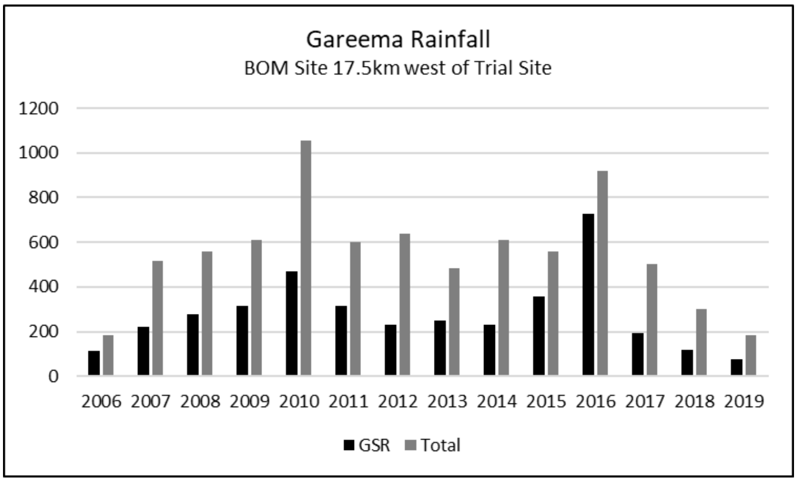

Figure 1. Gareema rainfall 2006 – 2019

Over the 13 years of the trial with treatment 20P 60N there has been 944 kg/grain yield/N removed and 630 kg/urea/N applied for a negative nitrogen balance of -314 kg/N (see table 2 and figure 2).

The 20P 120N treatment has seen 998 kg/grain yield/N removed and 1260 kg/urea/N applied for a positive nitrogen balance of +262 kg/N.

Table 2. A trial grain nitrogen N/kg/ha removal and nitrogen kg/ha applied 2007-2019

Applied N/kgs/ha	07	08	09	10°	11	12	13	14	15	16°	17	18	19	Total N/kgs/ha Removal
20P60N (630N	5*	80	70	247#	73	100	84	25*	110	77	41	26*	6	944N (-314N)
20P120N (1260N)	6*	70	72	234#	74	100	91	25*	138	115	40	26*	7	998N (+262N)
40P120N (1260N)	6	94	80	255	88	90	91	27	122	111	52	25	9	1047N (+213N)
20P (0N)	4	65	69	238	75	95	68	20	62	52	33	19	7	-807N
0P0N	3	65	51	240	40	66	48	5	37	49	12	20	9	-645N

* No top dressed urea
# Albus lupins no urea applied, N removal grain % x grain yield
° Significant waterlogging event (see figure 1)

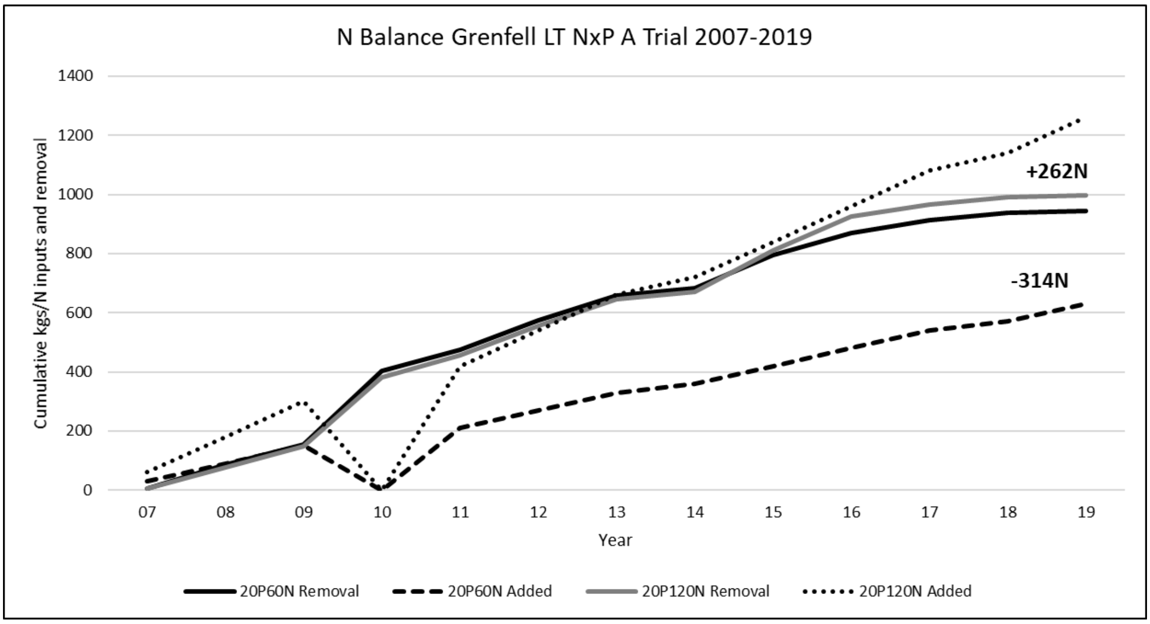

Figure 2. N balance at Grenfell trial 2007 – 2019

The grain yield nitrogen removal for the 20P0N treatment over the current life of the trial has a negative balance of -807 kg/N. Up until 2013 starting profile nitrogen from the field pea crop in 2007 and the albus lupin crop in 2010 have supplied sufficient nitrogen to achieve comparable grain nitrogen yield to the 20P60N and 20P120N treatments.

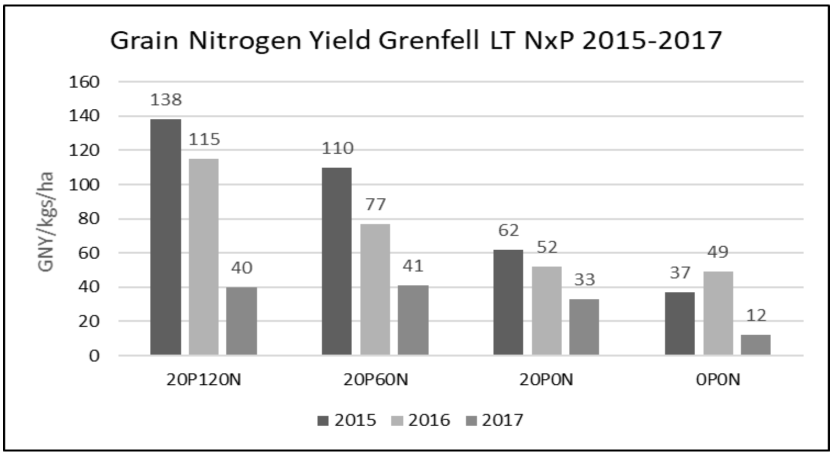

Figure 3. Grain nitrogen yield at Grenfell 2015-2017

The total soil nitrogen pool is being drawn down to an unsustainable level in the 20P60N treatment by removing more N than what is coming into the system (See Figure 4) through mineralisation. In a 500 mm average annual rainfall zone 2-3% of soil total N is mineralised during an average year in southern Australia. This represents 28-42 kg N/ha from a topsoil containing 1% OC (Angus 2016).

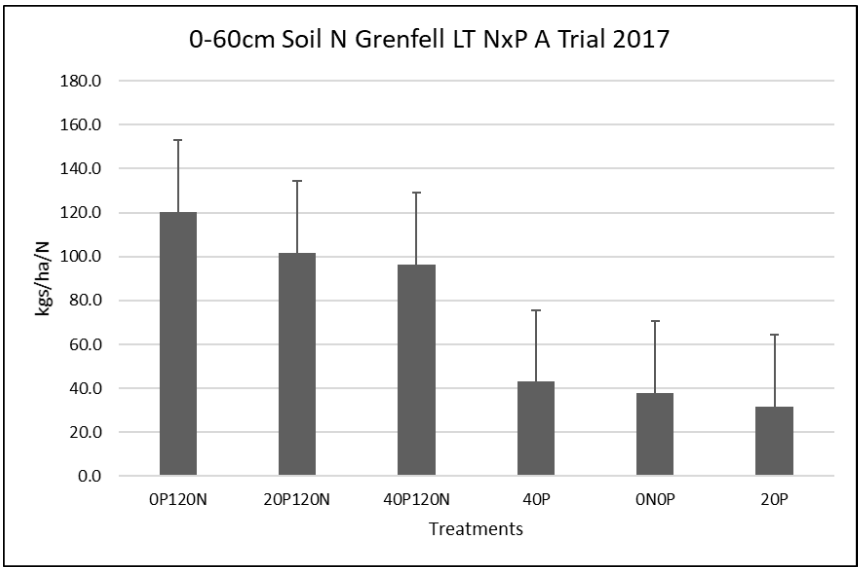

Figure 4. 0-60cm soil N at Grenfell long term NxP A trial 2017

As soil organic carbon levels continue to decline at this site (see Figure 5) and if a pulse crop isn't included in the rotation, total soil nitrogen is likely to decline further.

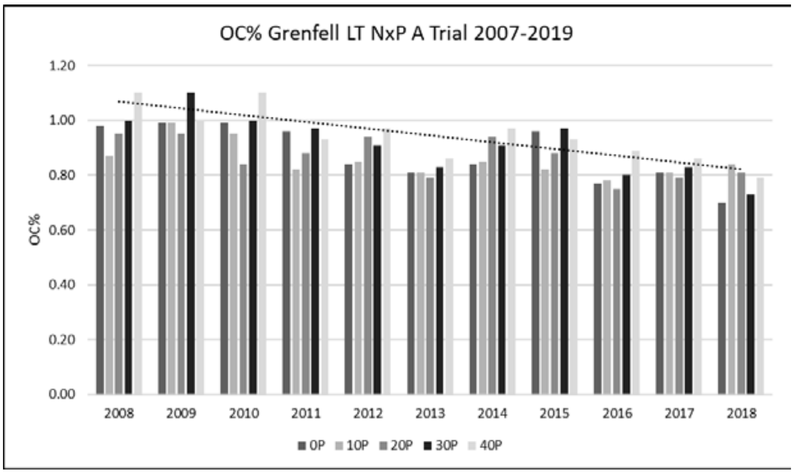

Figure 5. Organic carbon % at Grenfell long term NxP A trial 2007-2019

After 14 years of continuous cropping in an experiment at Harden, NSW, the daily rate of mineralisation, as a percentage of the total nitrogen present, was 30% less than the rate measured after 3-6 years of cropping. This decrease was in addition to the decrease present due to a fall in total organic matter and suggests the quality of organic matter has also decreased. (Angus 2006)

The N balance (Figure 2) also shows the effect of the ongoing drought with the grain yield nitrogen removal declining and continued application of urea nitrogen increasing the cumulative urea nitrogen.

When conditions allow, segmented deep nitrogen sampling will identify where that nitrogen is lying in the soil profile.

Additional research at the Grenfell site, completed, ongoing and proposed includes inquiry on the following issues: 10-30cm BSES P/Colwell P/PBI, 0-10cm DGT P/Colwell P, Mehlich-3, sulphur deficiency in canola, random sampling vs "kitchen method", pH of fertiliser band and surrounding soil, sub-soil acidity, soil boron, diffusion of phosphorus in fertiliser bands, crop response to residual phosphorus, crop response to residual urea nitrogen, urea use efficiency.

Acknowledgements

Thanks to trial site co-operators, Duncan Lander 2007-2015, David Partridge 2016-2019 and Kaylx for managing the site.

Reference

Angus J and Grace P (2017). Nitrogen balance in Australia and nitrogen use efficiency on Australian farms. Soil Research 55,435-450 http://www.publish.csiro.au/SR/SR16325

Angus J (2006). Budgeting crop nitrogen supply better estimation better decisions. GRDC Grains Research Update paper. Retrieved from: https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/budgeting-crop-nitrogen-n-supply-better-estimation-better-decisions

Angus J (2006). Targeted inputs makes sense. Farming Ahead No 173 June 2006

Gupta VVSR (2016). Factors affecting N supply from soils and stubbles. GRDC Grains Research Update paper Retrieved from: https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/02/Factors-influencing-nitrogen-supply-from-soils-and-stubbles

Simpfendorfer S (2015). Crown Rot an update on latest research. GRDC Grains Research Update Paper. Retrieved from: https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/07/crown-rot-an-update-on-latest-research

Smith, CJ, Dunin FX, Poss R, and Angus JF (2000). Nitrogen budget of wheat growing on a Riverine clay soil. Aust. J. Agric. Research 51, 867–76.

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Nutritional decision making for 2020

Panel session

Notes

Maintaining wheat yield under high temperatures - how do current cultivars compare with what's coming?

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Keywords

wheat, heat tolerance, genomic selection, phenotyping, pre-breeding

GRDC code

US00081

Take home message

- Recent Australian wheat cultivars are heat tolerant. However, new materials developed from diverse genetic backgrounds using field-based phenotyping and genomic selection suggest that levels of heat tolerance can be substantially improved.

Introduction

Periods of extreme high-temperature, particularly short periods of heat shock are a major threat to wheat yield and grain quality throughout much of the Australian wheat belt. Current projections of Australian climate change indicate that heat waves and temperature variability will become more frequent and more intense in the coming decades (CSIRO 2011, Climate Change in Australia. http://climatechangeinaustralia.com.au). It is vital that new wheat germplasm with improved high-temperature tolerance and molecular tags linked to this tolerance are developed and introduced into commercial breeding programs.

Genomic selection is a breeding method that requires a reference population of wheat lines that are phenotyped for the trait of interest and genotyped using many DNA markers distributed across the whole genome. Statistical methods are then used to estimate the effect of each DNA marker on the phenotype; the collection of all these DNA marker effects provides a prediction of genomic breeding value. This information can then be used to predict the phenotype of new plants that have known genotypes but not phenotypes. This allows early selection of plants/lines without phenotyping which decreases the breeding cycle leading to increased genetic gain.

Methods

A highly diverse set of agronomically adapted materials were assembled for phenotyping. These included thousands of new lines developed by the University of Sydney, including crosses with synthetic wheat, emmer wheat collected in warm areas, landraces, adapted germplasm with putative tolerance identified in hot wheat growing areas globally, Australian wheat cultivars and other sources of heat tolerance developed by others.

These materials were phenotyped for various traits; including yield, using a three-tiered strategy. Firstly, thousands of lines were evaluated in the field in replicated yield plots at Narrabri in northwestern NSW at different times of sowing. Later, sown materials were exposed to greater heat stress. Subsets of materials, based on performance in the previous year and estimated genetic values, were sown at sites in Western Australia (WA) and Victoria (Vic) to assess the transferability of traits. Each year, high performing lines were retained from the previous year, intolerant materials removed, and new materials added. Materials identified as heat tolerant in the times of sowing experiments were subsequently evaluated in the field during reproductive development using heat chambers to induce heat shock to confirm heat tolerance. Finally, those lines that maintained heat tolerance in the heat chambers were screened in temperature-controlled greenhouses to assess pollen viability under heat stress. Materials surviving all three stages of testing were considered highly heat tolerant.

All materials (>2000 lines) phenotyped in times of sowing experiments were genotyped using a 90K Single Nucleotide Polymorphism (SNP) platform and these formed the reference population for genomic selection from which all DNA marker effects were estimated. A prediction equation was developed and used to calculate genomic estimated breeding values (GEBVs) on selection candidates which were genotyped but not phenotyped. A genomic selection model that incorporated environmental covariates (for example; temperature, radiation and rainfall) directly was developed. This allowed the prediction of line performance under high temperature conditions. Environmental covariates were defined for each plot and growth development phase (vegetative, flowering and grain fill). An in-field validation of GEBV selected lines was then conducted by correlating GEBVs with field trial phenotypes. Various cycles of crosses were made among diverse lines with high GEBVs and progeny subsequently selected for high GEBV. These form the basis of our new elite heat tolerant materials.

Results

Extensive field-based phenotyping over a six-year period identified lines with superior adaptation to terminal heat stress (Figure 1). The tolerance of these materials was then confirmed in field-based heat chambers. The heat chambers were calibrated over a three-year period in replicated, triplicate plots (Table 1). Heat shock at anthesis significantly reduced yield compared to an ambient chamber and the uncovered plot. The ambient and uncovered plot were not significantly different from each other, and therefore, all future screening was conducted as paired plots (with and without heat chambers). The developed genotype-by-environment interaction genomic selection model increased genomic prediction accuracy for yield by up to 19%.

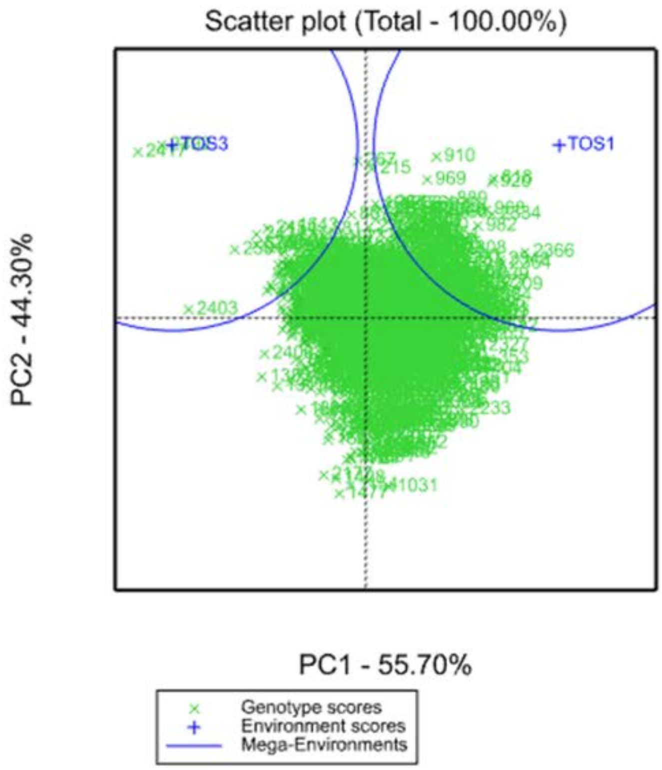


Figure 1. Genotype-by-environment interaction (GGE) biplot of yield in optimal (TOS1) and late (TOS3) sowing at Narrabri, 2013 to 2018.

Table 1. The impact of heat chambers on yield, kernel weight, kernel number and other traits, 2013 to 2015.

	Treatment			
	Ambient	Heated	No Chamber	Prob.
Yield (kg/ha)	2775 a	2248 b	2849 a	<0.001
TKW (g)	32.5	32.4	32	ns
Height (cm)	82.1	85.5	82.8	ns
Screenings%	4.09	4.89	5.13	ns
Grain number/10 spikes	49.3 a	43.8 b	48.74 a	<0.002

n.b. Means in the same row followed by different letters are significantly different.

The most heat tolerant Australian cultivars evaluated between 2013 to 2018 were the older varieties; Sunco, Annuello, ScoutⓅ, Sunstate and LangⓅ. These cultivars showed little difference in yield between times of sowing over years (Figure 2) but tended to have relatively low yield potential. However, the higher yielding, more recent varieties; EGA GregoryⓅ, SuntopⓅ and SpitfireⓅ tended to have reduced heat tolerance. Several recently derived pre-breeding lines (PBI09C034-BC-DH38, PBI09C028-BC-DH56, PBI09C026-BC-DH5) have combined both high yield and heat tolerance.

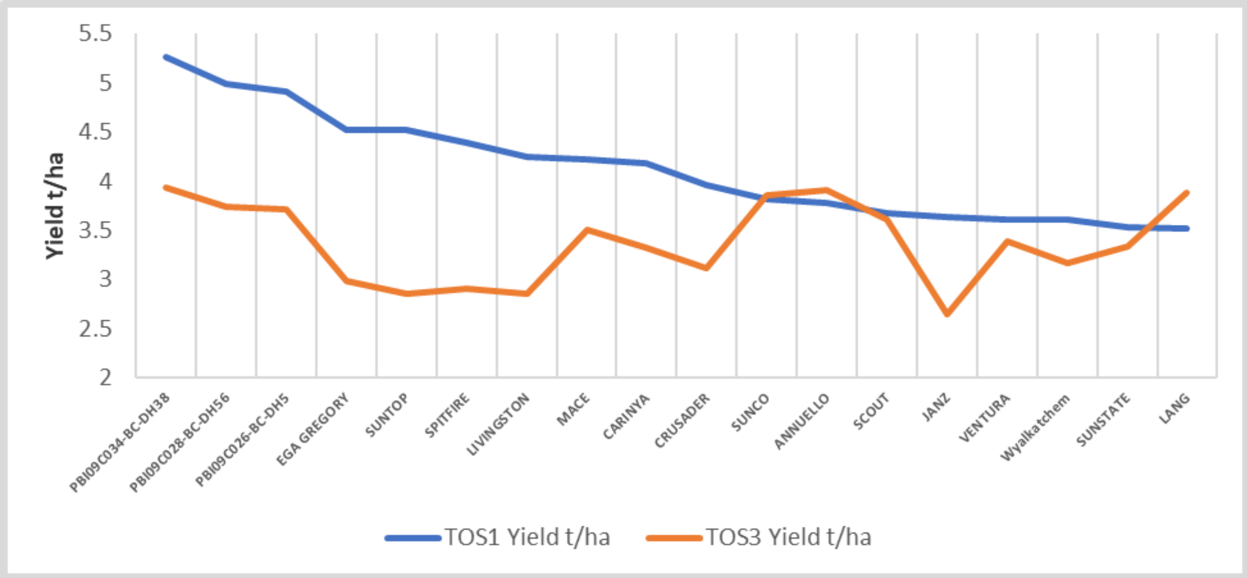


Figure 2. Yield at Narrabri (2013 to 2018) for heat tolerant lines and Australian cultivars for two different times of sowing (TOS1 and TOS2 are optimal and late sowing, respectively).

A wider range of Australia cultivars, including many recent releases, was included in 2019 (Figure 3). Mustangⓓ, Scepterⓓ, Maceⓓ, Sunmateⓓ and Borlaugⓓ all showed relatively high levels of heat tolerance. Mustangⓓ and Scepterⓓ combined this with high yield. The pre-breeding lines PBIC15020-0C-60N-010N and PBIC15022-0C-6N-010N, developed using genomic selection, also combined high yield with heat tolerance. Unlike Mustangⓓ, these materials flowered later and did not escape the high temperatures during grain fill.

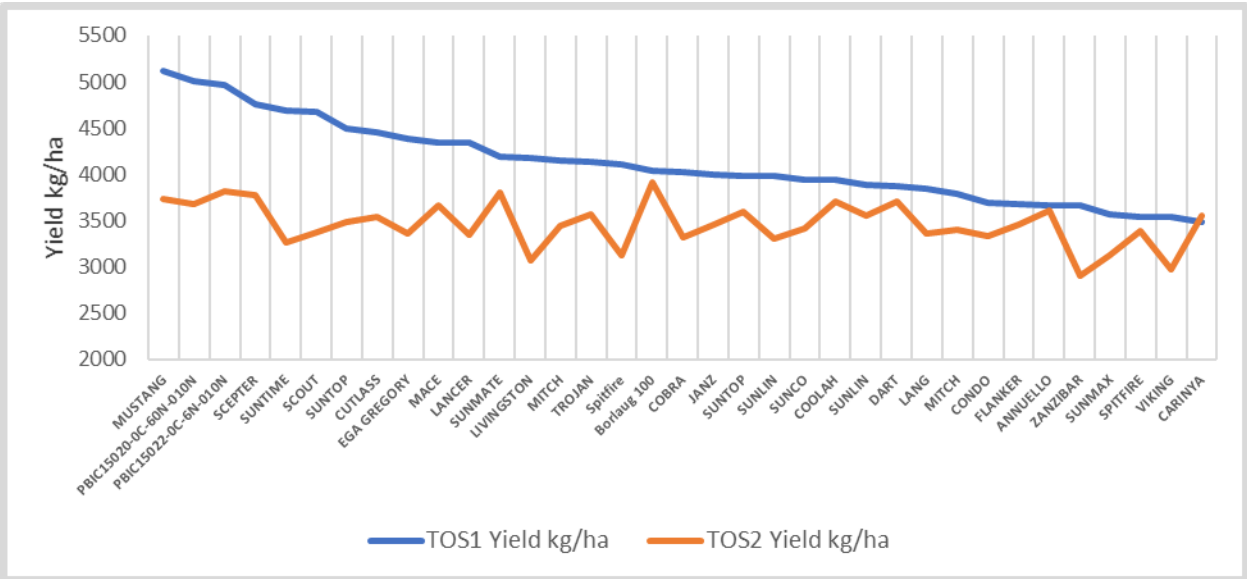
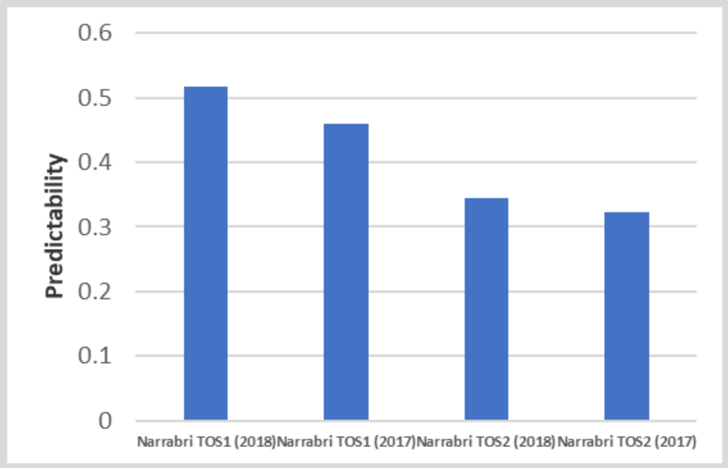


Figure 3. Yield of Australian cultivars and new heat tolerant lines at Narrabri, 2019 for two different times of sowing (TOS1 and TOS2 are optimal and late sowing, respectively).

An important aspect of this work was the transferability of the Narrabri results to other regions of Australia. Subsets of 200 lines, selected for high GEBV, were evaluated at Merredin and Horsham to validate the strategy. A training population was necessary to allow genomic prediction models to calculate GEBVs without the need for phenotyping at other sites. The accuracy of genomic prediction for yield, trained at Narrabri, was evaluated in 2017 and again in 2018 (Figure 4). When the 2018 data were included in the estimations of GEBVs, the predictability exceeded 0.5 for both early and late times of sowing.

A. Merredin



B. Horsham

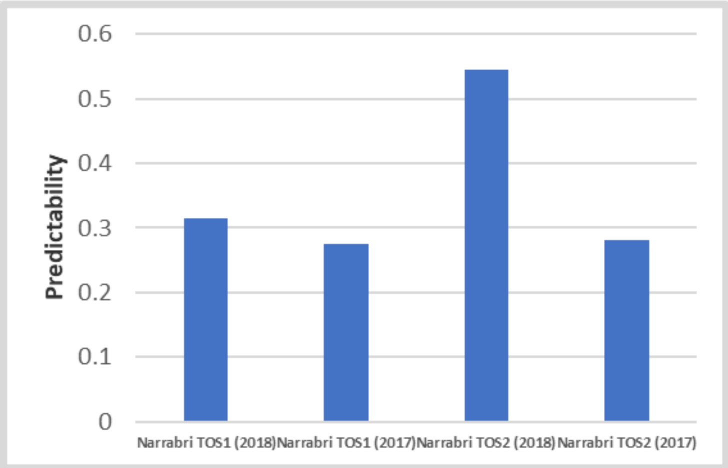


Figure 4. Accuracy of genomic prediction for yield trained at Narrabri (GEBVs calculated from five and six years of data) and validated at Merredin and Horsham in 2017 and 2018. TOS1 and TOS2 are optimal and late sowing, respectively.

Conclusion

Some recently released Australian cultivars have both the genetics of high yield and the genetics for heat tolerance. However, new pre-breeding materials developed using genomic selection offer commercial wheat breeders' new sources of diversity for both yield and heat tolerance that can be used to mitigate the effects of a warming environment. The strategy of selecting for heat tolerance at Narrabri for other regions of Australia was validated by the relatively high correlations between GEBVs and yield under heat stress at Merredin and Horsham.

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References

CSIRO, 2011, Climate Change in Australia. http://climatechangeinaustralia.com.au

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Practical applications for earlier sowing of cereals - how does it work in central NSW?

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Notes

Yield stability across sowing dates: how to pick a winner in variable seasons?

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Keywords

flowering time, adaptation, sowing opportunity

GRDC code

DAN00213 (Grains Agronomy and Pathology Partnership, GRDC and NSW DPI)

Take home messages

- Match optimal flowering period to growing environment to maximise grain yield potential
- One variety doesn't fit all; there are no commercially available varieties that are broadly adapted across a wide range of sowing times or growing environments
- Optimising variety phenology and sowing time combinations achieves grain yield stability across a wide sowing window
- Probability of sowing opportunities will influence variety choice and sowing time decisions.

Background

Across the northern grains region (NGR), wheat is sown across a window from early to late autumn (April–May). There are a range of commercial cultivars which vary in their phenology from slow developing winter types to fast developing spring types, providing growers with flexibility in their sowing window. Field experiments were sown at ten locations in the NGR to determine phenology and yield responses across different environments. The experiments were conducted from 2017 to 2019, and annual rainfall at the ten locations ranged from 184mm to 620mm. The aim of these experiments is to provide growers with regional information about variety adaptation and recommended sowing times.

Aim to target optimal flowering period (OFP) for your growing environment

Across the environments of the NGR, one of the primary drivers of yield and grain quality is flowering time. When considering variety options at sowing, growers should aim to synchronise crop development with seasonal patterns so that flowering occurs at an optimal time. This period is a trade-off between increasing drought and heat threat, and declining frost risk. Across the NGR, the optimal flowering period (OFP) varies from late July in central Queensland to mid-late October in southern NSW. There is no 'perfect' time to flower when there is no risk, rather there is an optimal period based on minimising risks, and maximising grain yield based on probabilities from previous seasons.

Previously, we proposed OFPs from simulations using the APSIM cropping systems for locations across the NGR, based on historical climatic records (1961–2018) according to the parameters outlined by Flohr et al. (2017) for a fast spring genotype (Harris et al., 2019). These OFPs have now been validated using recorded flowering dates and grain yield from field experiments conducted across the NGR from 2017 to 2019. It was determined that the OFP varies significantly in timing and duration, as well as for different yield levels across environments (Figure 1). As flowering time is a function of the interaction between variety, management and environment; the variety x sowing time combinations capable of achieving OFP and maximum grain yield also varied across environments of the NGR (Figure 1).

In very dry seasons, such as 2019, yields are often higher when the crops flower earlier than the OFP; while in wetter seasons, such as 2016, flowering later does not induce the same yield penalties. Despite this, our field data supports the idea that growers should target the OFP for their growing environment to achieve maximum grain yield potential.

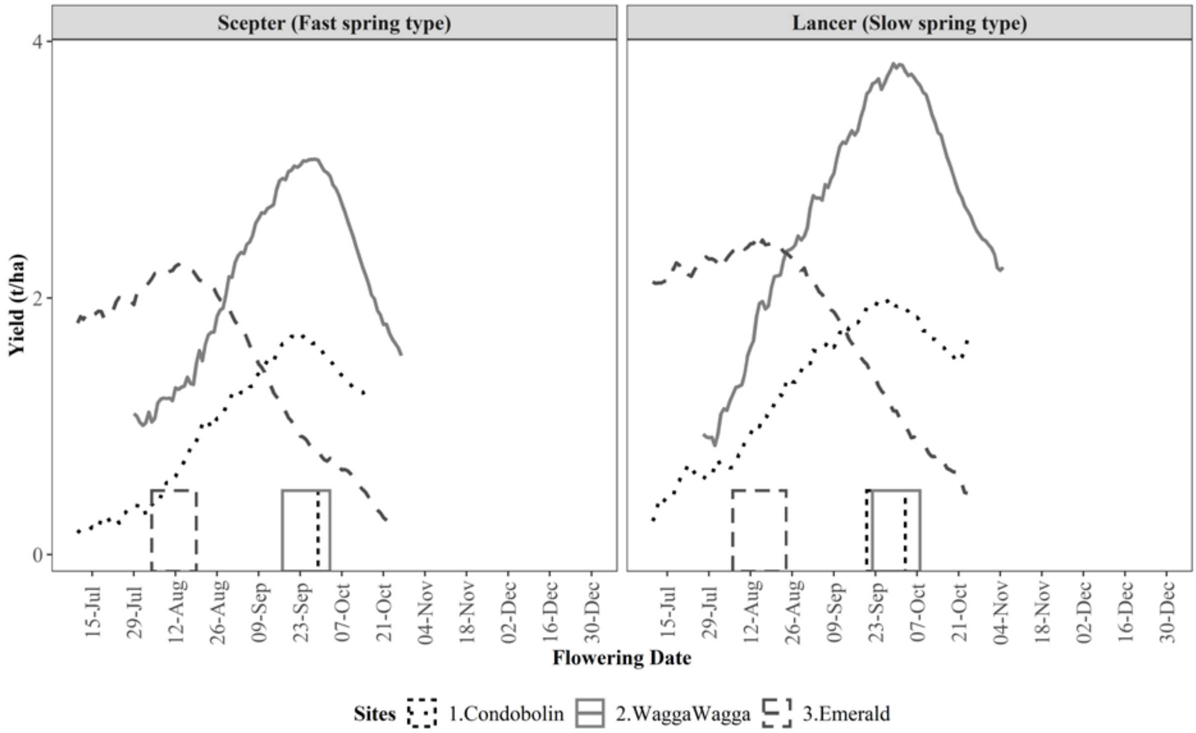

Figure 1. The optimal flowering period (OFP) for a fast spring variety (Scepter⁽ᴅ⁾) and a slow spring variety (Lancer⁽ᴅ⁾) determined by combining field data from experiments (2017-2019) and APSIM simulation using methods of Flohr et al. (2017) for Condobolin, Wagga Wagga and Emerald. The lines represent frost and heat limited yield (kg/ha), while the boxes on the x-axis represent the predicted OFP defined as ≥ 95% of the maximum mean yield.

One cultivar doesn't fit all - need to match variety and sowing time

Timing of flowering is influenced by phenology (genotype (G)), location and season (environment (E)) and sowing time (management (M)). Significant G × E × M interactions influencing grain yield responses across environments have been identified. The implication of these findings is that there are no commercially available varieties that are broadly adapted across a wide range of sowing times or growing environments. Differences in seasonal rainfall and temperature extremes imposed during the critical flowering period, which could have been influenced by sowing time, indicated that variety performance is also highly dependent on season. Despite this, there is evidence to suggest that variety choice can be exploited by growers to achieve OFPs and relatively stable yields across a wide sowing window. For example, in Wagga Wagga, southern NSW, winter wheat (for example; LongReach⁽ᴅ⁾, Kittyhawk⁽ᴅ⁾ and Longsword⁽ᴅ⁾) require earlier sowing to flower within the optimal period, due to their extended phase duration and slower development pattern. Slower developing spring types (for example; Lancer⁽ᴅ⁾) are suited to late-April, early-May sowing dates, while mid to fast spring types (for example; Beckom⊕, Condo⊕) are sown mid-late May to synchronise development and target the OFP (Figure 2).

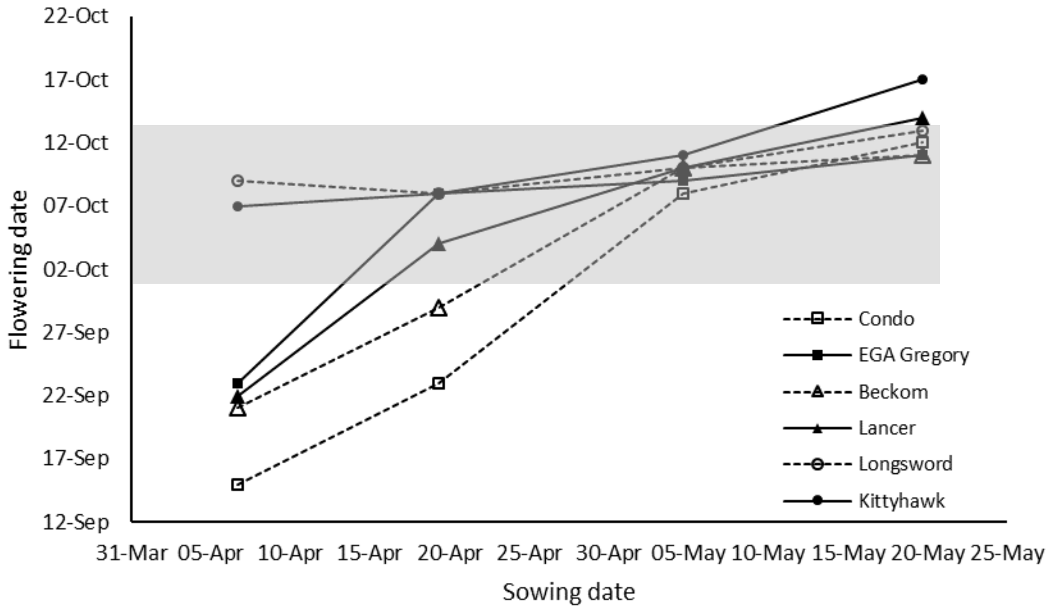

Figure 2. Mean heading date responses from selected winter and spring cultivars at Wagga Wagga (2017-18) and Marrar (2019) across all sowing times. Shaded area represents the optimal flowering period.

In southern NSW, when slower developing varieties (for example; winter type EGA Wedgetail⊕) are sown early and achieve OFP, they are capable of higher water-limited yields compared with faster developing spring varieties sown later. However, faster developing varieties (for example; Scepter⊕) are better adapted to regions with shorter growing seasons, and in environments or later sowing scenarios where frost and heat stresses occur in close proximity to each other (Figure 3).

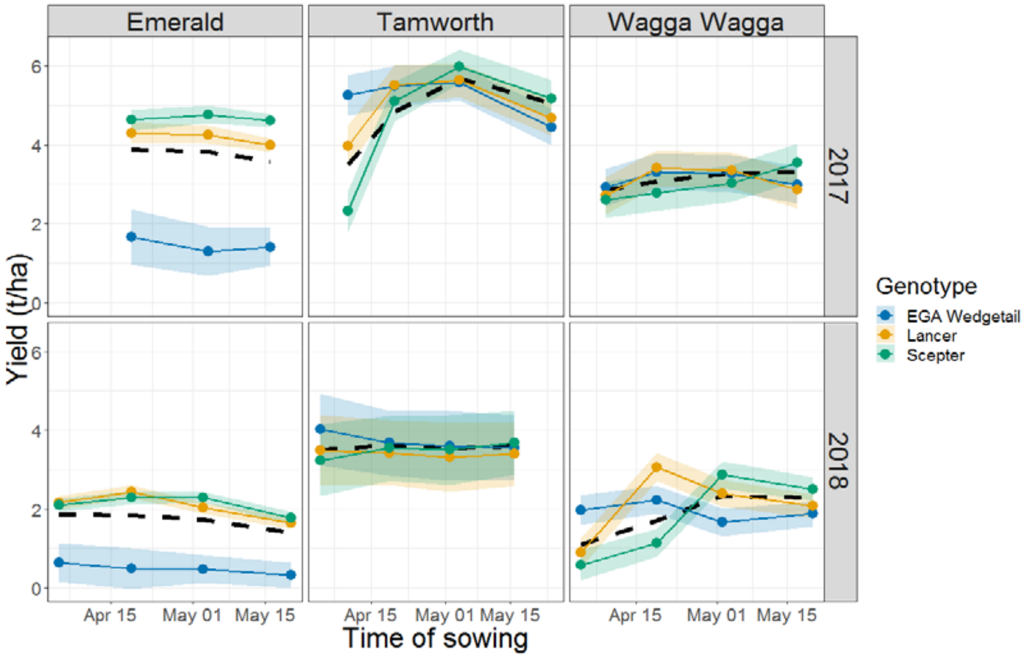

Figure 3. Predicted grain yield responses across sowing dates from early-April to late-May at Emerald, Tamworth and Wagga Wagga sites in 2017 and 2018 for selected genotypes; EGA Wedgetail⦶ (winter type), Lancer⦶ (mid spring type), Scepter⦶ (fast spring type).

Likelihood and timing of sowing opportunities varies across growing environments

Matching flowering date to a growing environment can be a challenge, as the timing of the seasonal break is highly variable. A simulation was conducted to determine the probability of a sowing opportunity occurring across locations of the NGR using methods described in Unkovich (2010). According to this sowing rule, the timing of a sowing opportunity whereby there is sufficient seedbed moisture to establish a wheat crop, differs across environments. Therefore, sowing opportunities will influence variety choice and sowing time decisions also. For example, the probability of a sowing opportunity prior to 25 April was 38% at Condobolin, compared to 65% of years at Yarrawonga (Figure 4). As such, there are limited opportunities to sow a winter wheat at Condobolin, however probability increases to approximately 70% by early-May and the opportunities increase for mid-fast developing varieties. In contrast, growers in Yarrawonga have more flexibility in their sowing window and could consider incorporating slower developing or winter types for earlier sowing in their program.

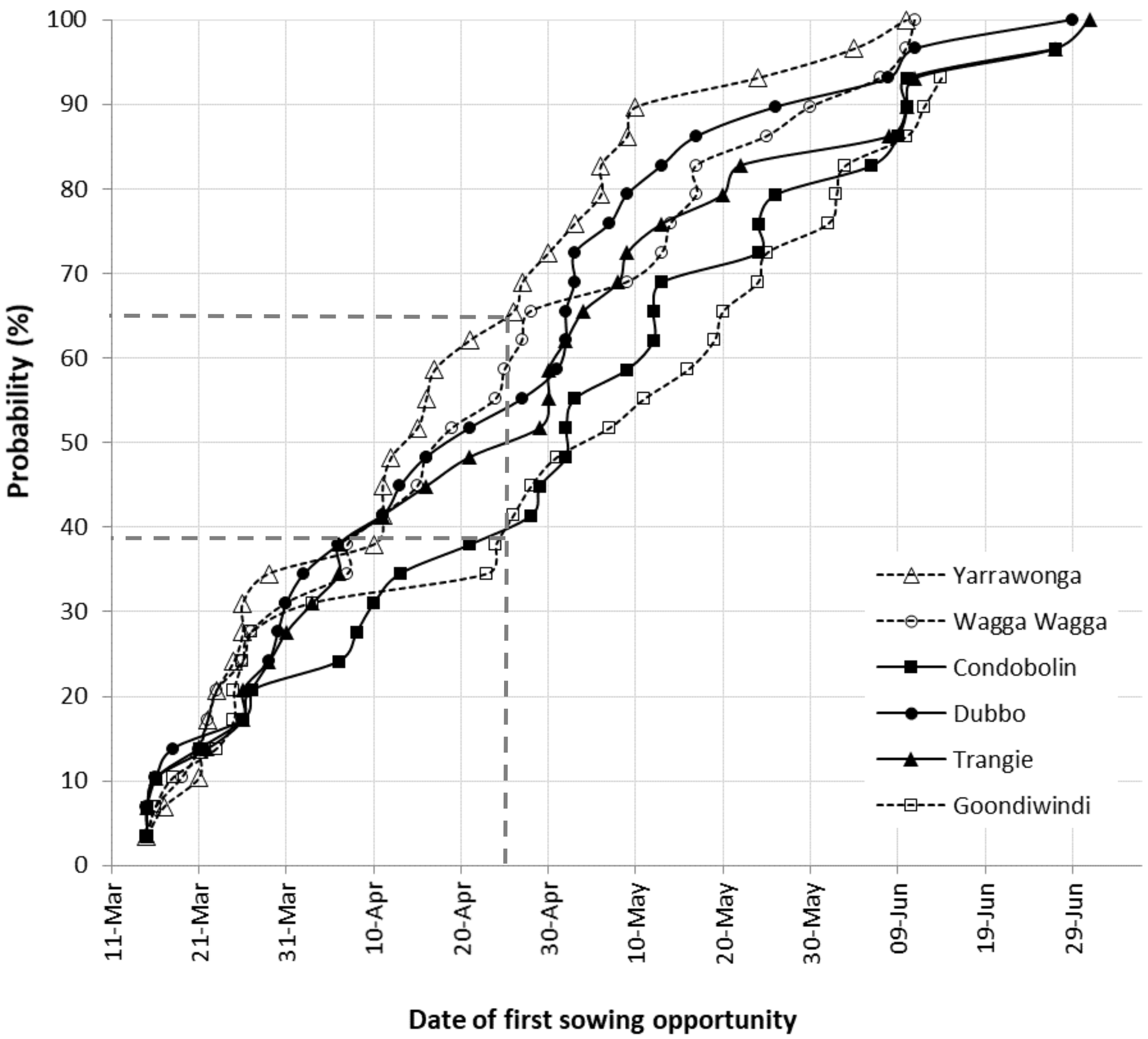

Figure 4. Probability distribution of first sowing opportunity for sites across the Northern grains region from 2000-2018 using the methods of Unkovich (2010). The dashed grey line pinpoints the probability of the sowing opportunity prior to 25 April for Condobolin and Yarrawonga.

Conclusion

There were significant interactions between G × E × M, whereby genotypic responses to sowing date varied across sites in the NGR, and within seasons for varieties with varied phenology patterns. These findings indicate that the varieties tested are not broadly adapted to environment or management, and as such there is scope for growers to optimise grain yield through variety selection and management of sowing date by considering phenology responses and target OFPs.

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References

Flohr, BM, Hunt, JR, Kirkegaard, JA, Evans, JR (2017) Water and temperature stress define the optimal flowering period for wheat in south-eastern Australia. Field Crops Research 209, 108-119.

Harris, F, Graham, R, Burch, D, Brooke, G, Matthews, P, Xing, H (2019) Hot vs Cold: balancing the risks associated with abiotic stresses in wheat. Proceedings of the GRDC Grains Research Updates, presented at Dubbo and Spring Plains, 2019.

Unkovich, M (2010). A simple, self-adjusting rule for identifying seasonal breaks for crop models. Proceedings of 15th Australian Agronomy Conference 2010, Lincoln, New Zealand

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How does phenology influence yield responses in barley?

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Keywords

optimal flowering period, frost, sowing date, adaptation

Take home messages

- The optimal flowering period (OFP) to maximise grain yield potential and minimise effects of abiotic stresses in barley is earlier than for wheat and varies across growing environments
- Flowering time and grain yield is optimised with different variety x sowing date combinations, and varietal suitability varies across growing environments
- Relative frost risk of barley is lower than for wheat, and commercial barley varieties differ in frost tolerance

Background

Maximum grain yield potential is achieved when crop development is synchronised with growing environment. Typically, barley is sown in a window from early–late autumn (April–May), to ensure flowering occurs at an optimal time in spring. This optimal flowering period (OFP) is defined early, by the risk of reproductive frost damage, and later, by high temperatures and terminal water stress during grain filling. Barley is considered to be more widely adapted, have superior frost tolerance, and has a yield advantage compared to wheat across environments of southern Australia (Harris et al., 2019), despite this, OFPs for barley have not been adequately defined which has implications for variety choice and sowing dates for growers.

Field experiments – Condobolin and Marrar, 2019

In 2019, field experiments were conducted at Condobolin and Marrar to investigate interactions between phenology, sowing date and growing environment. Cultivar responses were significantly influenced by seasonal conditions, with both sites recording below average growing season rainfall (April to October) and severe heat stress events which coincided with the late flowering to early grain filling period (Table 1).

Table 1. Growing season rainfall (GSR) April to October, frost and heat events at Condobolin and Marrar, 2019.

Site	GSR (mm)^	Frost events (days <0°C)	Heat events (days >30°C)	Comments
Condobolin	144 (246)	5	9	• Minimal frost, no days <-2°C • Heat events coincided with late grain-filling phases: 1 day >30°C early October, 4 days >30°C late October-early November • 60 mm supplementary irrigation prior to sowing, additional 110 mm irrigation in-crop (May-September) to target Decile 5-6 yield potential.
Marrar	194 (272)	3	8	• Minimal frost, no days <-2°C • Heat events coincided with early grain-filling phases: 2 days >30°C early October, including 31.1°C (3 Oct) and 34.1°C (6 Oct); 7 days >30°C (23 Oct-2 Nov) • SD1 (18 April) established with 10 mm supplementary irrigation via drippers; site rain fed thereafter.

^Long term average (LTA) in parentheses

Phenology and yield responses to sowing date, 2019

Variety and sowing date combinations which flowered in early-mid September at Condobolin, and in mid-late September at Marrar achieved the highest yields in 2019. This indicates that OFPs vary in timing and duration across different yield environments, as described for wheat (Flohr et al., 2017). As flowering time is a function of the interaction between variety, management and environment, the variety x sowing time combinations capable of achieving OFP and maximum grain yield also vary across environments (Figure 1). At both sites, optimal flowering time were achieved by fast winter type Urambieⓓ sown mid-late April, spring cultivars sown mid-May, and some faster finishing spring types (e.g. La Trobeⓓ and Fathom ⓓ) capable of flowering within the optimal window when sown late-May. However in 2019, which was characterised by minimal frost risk, significant heat stress and terminal drought (Table 1), earlier flowering resulted in higher grain yields at both sites (Table 2).

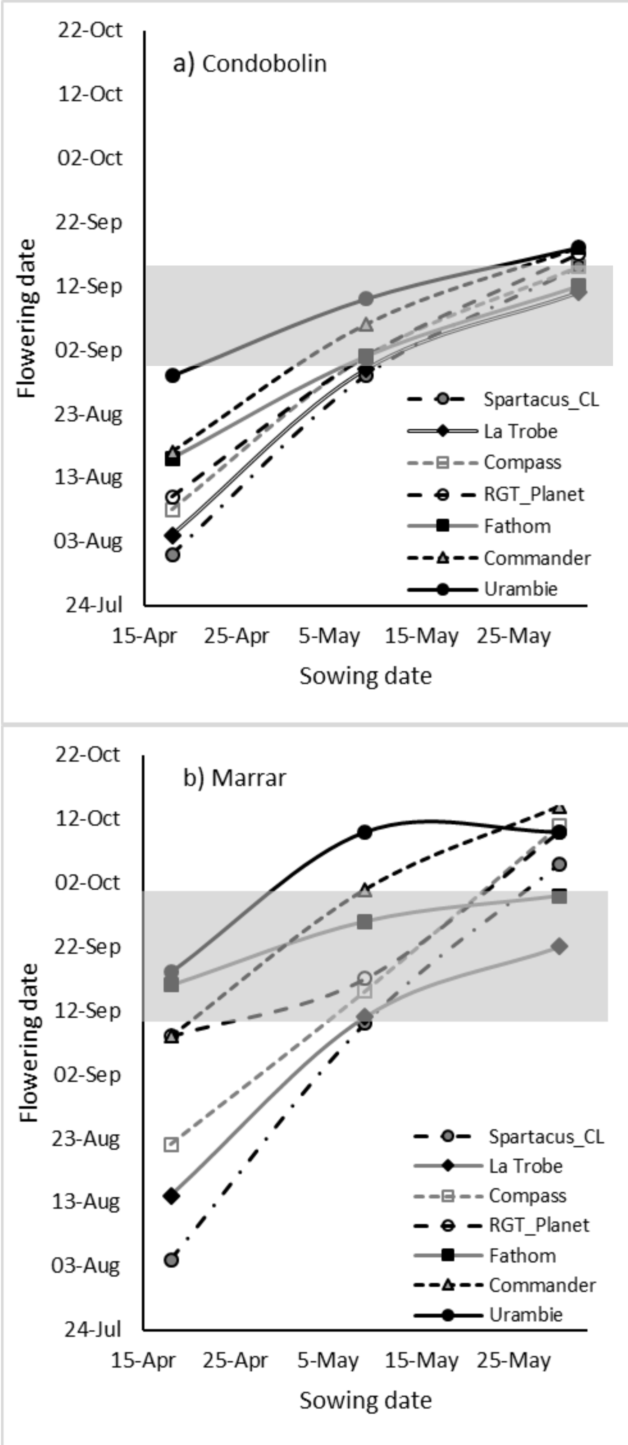

Figure 1. Flowering date responses to sowing date for selected varieties at a) Condobolin and b) Marrar field experiments in 2019. Shaded area indicates proposed optimal flowering period (OFP) at each location.

Table 2. Grain yield responses to sowing date for barley varieties at Condobolin and Marrar, 2019.

Variety	Condobolin			Marrar		
	18 April	9 May	1 June	18 April	9 May	30 May
Banks⑩ *(Mid spring)*	3.54	3.13	2.14	3.53	3.35	2.80
Biere⑩ *(Fast spring)*	2.64	2.65	2.00	3.67	2.66	2.59
Cassiopée *(French winter)*	1.59	1.17	0.79	1.80	1.64	1.17
Commander⑩ *(Mid spring)*	3.73	2.35	1.86	3.62	3.00	2.43
Compass⑩ *(Fast spring)*	4.00	2.99	2.56	3.96	3.09	3.03
Fathom⑩ *(Mid-fast spring)*	3.80	3.07	2.54	4.57	3.58	3.00
La Trobe⑩ *(Fast spring)*	4.05	2.90	2.54	4.28	3.42	2.69
RGT Planet⑩ *(Mid-fast spring)*	4.02	2.38	1.90	3.07	2.87	2.60
Rosalind⑩ *(Fast spring)*	3.54	2.71	2.93	4.06	3.76	3.07
Spartacus CL⑩ *(Fast spring)*	3.64	3.44	2.42	4.06	3.95	2.97
Traveler⑩ *(Slow spring)*	3.41	2.69	1.83	3.21	3.39	2.52
Urambie ⑩ *(Fast winter)*	3.49	2.41	1.96	3.54	2.74	2.51
Mean	**3.45**	**2.66**	**2.12**	**3.61**	**3.12**	**2.62**
LSD (Variety)	**0.54**			**0.31**		
LSD (SD)	**0.27**			**0.15**		
LSD (Variety x SD)	**0.93**			**0.53**		

How does barley optimal flowering period (OFP) compare to wheat?

A preliminary comparison of co-located wheat and barley field experiments conducted in two contrasting seasons (Wagga Wagga, 2018 and Marrar, 2019) suggests that the OFP, whereby grain yield was maximised, for barley is significantly earlier, and relative frost risk lower than wheat, which has implications for variety choice in relation to sowing time for growers (Figure 2).

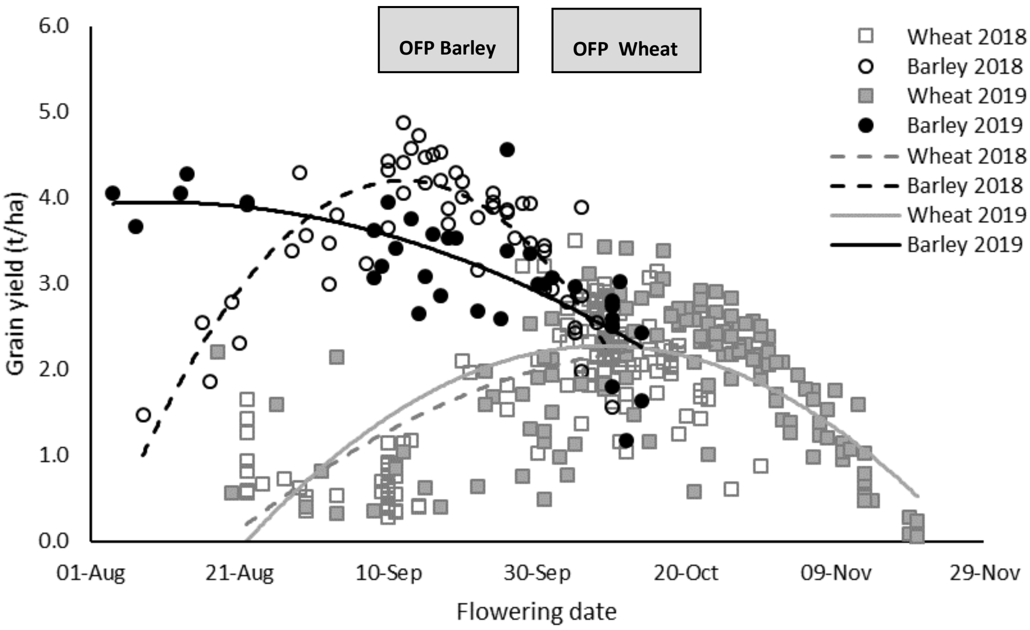

Figure 2. Grain yield responses to flowering date for a range of wheat and barley varieties sown from early April-late May in co-located experiments conducted at Wagga Wagga (2018) and Marrar (2019).

Cultivar adaptation to growing environment

A comparative analysis between yields of RGT Planet⦶ and La Trobe⦶ from field experiments conducted at Condobolin (2017-19), Matong (2017), Wagga Wagga (2016-18), Marrar (2019) and Wallendbeen (2018-19) showed that these cultivars often achieved similar grain yields (Figure 3). Generally, in environments where grain yields were less than 2.5-3 t/ha, or in seasons such as 2019, with severe heat and terminal drought stress, La Trobe⦶ or faster finishing types were favoured; whilst when grain yields were greater than 2.5-3 t/ha, RGT Planet⦶ was capable of a yield advantage. Differences in comparable yields were also apparent in relation to management, whereby RGT Planet⦶ offers an opportunity for slightly earlier sowing (early May) compared to benchmark fast spring type La Trobe⦶ which is better suited to traditional mid-late May sowing dates.

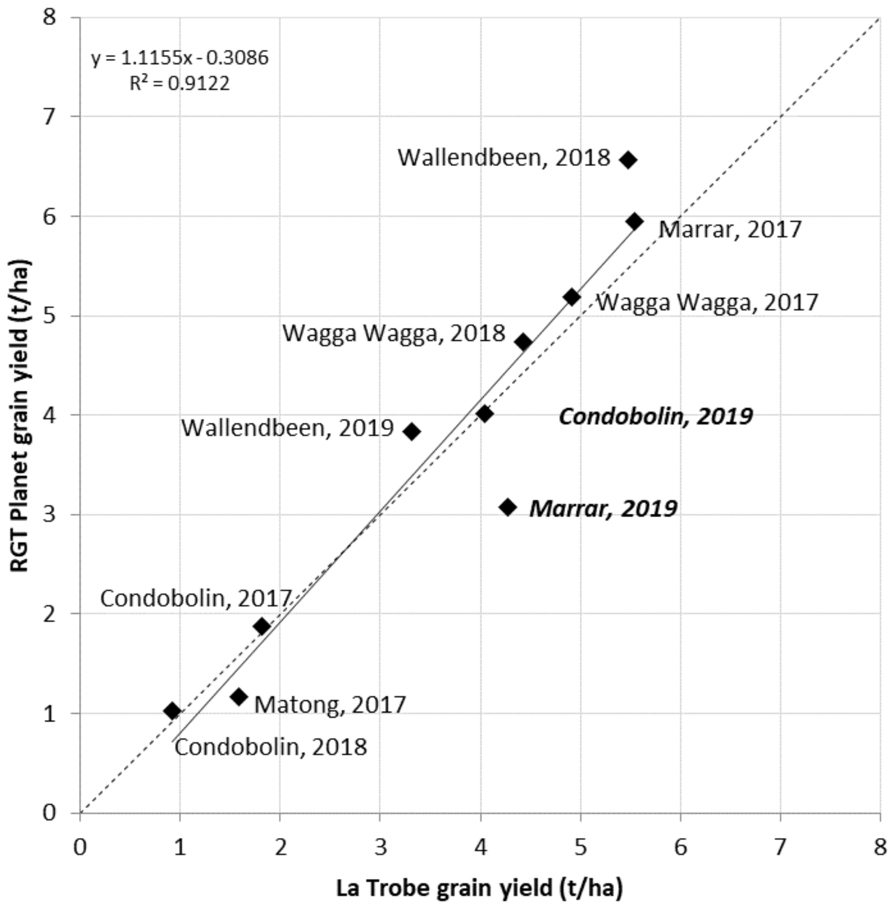

Figure 3. The relationship between highest yields of RGT Planet⦶ and La Trobe⦶ from field experiments at Condobolin (2017-19), Matong (2017), Wagga Wagga (2016-18), Marrar (2019) and Wallendbeen (2018-19). Dotted line indicates 1:1 relationship.

Varietal differences have been observed under high frost risk seasons, such as those experienced at Wagga Wagga in 2018, whereby RGT Planet⦶ was better able to maintain yield under frost conditions (SD1) compared to La Trobe⦶ (Figure 4). This aligns with the National Frost Initiative (NFI) barley variety rankings (Figure 5) which is a useful resource for both barley and wheat.

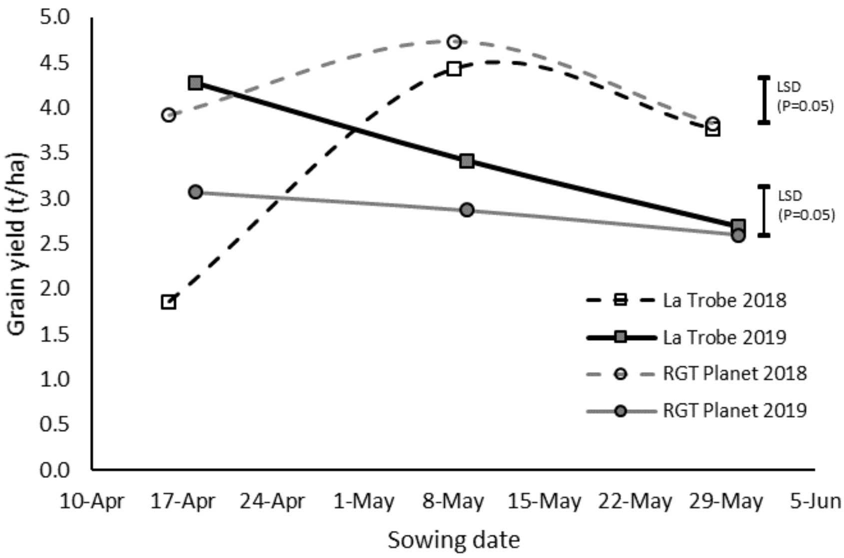

Figure 4. Grain yield responses to sowing date for RGT Planet⦶ and La Trobe⦶ at Wagga Wagga (2018) and Marrar (2019).

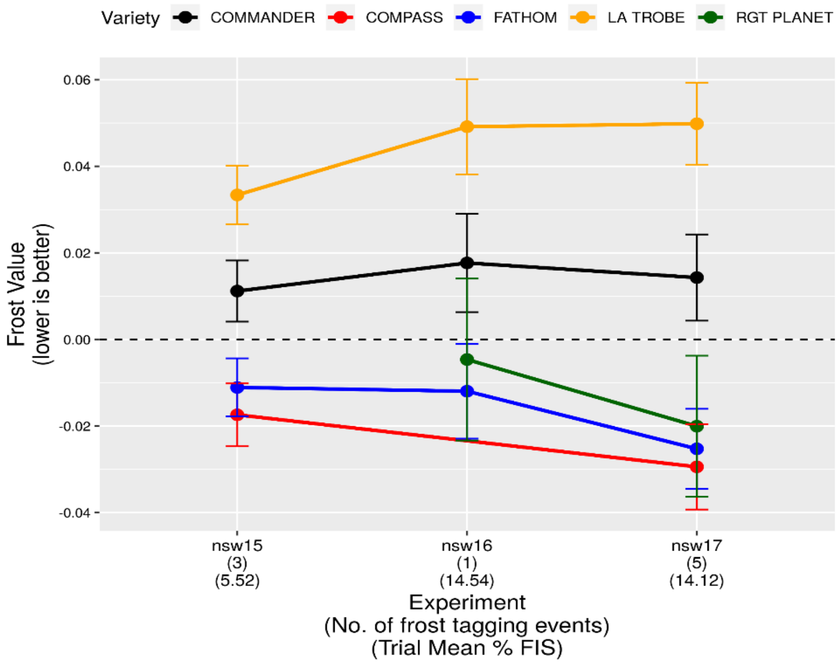

Figure 5. National Frost Initiative (NFI) variety rankings for selected barley varieties in northern region, based on experiments conducted in NSW (2015-2017).
Source: https://www.nvtonline.com.au/frost/

Conclusion

Initial comparisons indicate that the optimal flowering time (OFP) for barley is earlier than for wheat, and timing and duration of barley OFPs varies with environment. Timing of flowering and grain yield is optimised with different variety x sowing date combinations, and variety responses and suitability differ across growing environments. Most spring barley varieties are still suited to traditional May sowing dates, however some longer season spring types such as RGT Planet⦶ offer opportunities for slightly earlier sowing (early May) compared with benchmark fast spring types such as La Trobe⦸. Whilst early sowing options in frost prone environments of southern NSW are currently limited by suitable winter varieties, there are differences in relative frost susceptibility within current commercially available varieties in NSW.

Useful resources

https://www.nvtonline.com.au/frost/

References

Flohr, BM, Hunt, JR, Kirkegaard, JA, Evans, JR (2017) Water and temperature stress define the optimal flowering period for wheat in south-eastern Australia. Field Crops Research 209, 108-119.

Harris, F, Burch, D, Porker, K, Kanaley, H, Petty, H, Moody, N (2019). How did barley fare in a dry season? Presented at the GRDC Grains Research Update, Wagga Wagga, February 2019.

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Integrating livestock into cropping systems- agronomy, dry matter production, time of sowing & nutrition

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Notes

Wire, water and grazing management in dual purpose crops

David Harbison, D R Agriculture Pty Ltd, Molong

Key words

paddock layout, fencing, water, dual purpose crops

Take home messages

- Paddock size, or available grazing area, is key to maximise grazing efficiency
- Strip fencing may be necessary to 'create' the required stock density
- Water sources must be of good quality and well located within each paddock
- Identify the class of stock and their indicative weight and consumption needs before sowing to determine the likely area of grazing crop needed (use regional dry matter crop growth rates to assist)
- Increased profitability per hectare gross margin by comparison to crop only situations.

Introduction

Dual-purpose crops offer great opportunities for farmers with livestock in their system (their own or via potential agistment income) to utilise early-season sowing opportunities, spread risk, and increase per hectare (ha) returns. Critical to gaining the most from these opportunities, is getting much of the logistics right, and applying sound grazing management. Cropping machinery (in general) over the last 20 – 30 years has been getting larger and more efficient. As a consequence, livestock infrastructure has been reduced, and in many cases, removed. So, what does this mean for dual purpose crops? In short, many paddocks are now too large to graze efficiently. Water points are often minimal and of lesser quality and quantity, or the number of stock required to provide efficient grazing can be very large - creating its own sub-set of management issues.

Kirkegaard et al. (2016) reported that with good management, the period of grazing can increase net crop returns by up to $600/ha and have a range of system benefits including widening sowing windows, reducing crop height, filling critical feed gaps and spelling pastures. However, achieving this grazing return relies heavily on 'good management', with time of sowing, stock number, grazing management, crop growth (both pre grazing and recovery), water supply and other factors all critical to a successful outcome. The indicative stock density used to achieve the above profit was approximately 2000 dry sheep equivalent (dse) grazing days/ha. Put simply, it may be 40 dse/ha for 50 days of grazing.

Paddock infrastructure

There is no 'ideal' paddock size, or available grazing area. My experience is that smaller paddocks/areas (<40 – 50 ha) are likely to be far easier to manage and have more manageable water points than much larger paddocks. Getting the most from the grazing dry matter (DM) requires eating more of what is on offer, over a shorter period of time, and leaving a critical residual biomass to allow significant crop regrowth before the second (and potentially third) grazing. Understanding crop growth rates, and what drives them, from planting to first graze (autumn) and into winter, enables farmers and advisors to predict likely stock numbers and DM production. Stock number and predicted consumption determines how long a set amount of DM will last. Using the grazing day information from Kirkegaard et al (2016), a 40 ha paddock would require approximately 1600 dse (potentially 2000 lambs (or 230 - 250 weaner steers depending on size)) for two 25 day grazings. A paddock larger than this will proportionately increase the stock number needed to optimise grazing efficiency.

A significant limitation to larger paddocks (and by default mob size) is water. This is usually the most difficult infrastructure to accommodate in the dual purpose crop system. Many issues surround good stock water supply. Distance to, temperature and cleanliness of water, dam vs trough, and other factors all impact on animal intake and performance.

The Dept. of Primary Industries and Regional Development WA (2020) publication 'Water quality for livestock', guides farmers in the water needs of livestock. Stock avoid warm water, so deeper or shaded water sources will generally be preferred. Pipes carrying water above ground to moveable troughs may deliver hot and undrinkable water (pending time of the year and location). Similar outcomes can also occur in shallow troughs in full sun. While trough systems have many benefits, if mob size is too large or inflow rates too low, stock will walk off with less (and sometimes nil) water intake. Allowing at least one metre of trough per 130 sheep is their advice. Further, sheep not used to water troughs, and particularly young sheep, may take time to learn to drink from them, so always push them onto water in a new paddock.

Dams are still very valuable, and often the only option for many. If there has been a benefit of the recent drought and dry dam situation, it is the opportunity provided to clean out those dams that farmers will benefit from most into the future. Stock will always decrease the quality of dam water, often by urine and faeces contamination and most commonly just by mud and foot disturbance. If water quality is poor, livestock may drink less than they need, or rarely, may stop drinking altogether. Lower water intake decreases DM intake, thus resulting in decreased animal performance. Many experiments have demonstrated the benefits of cleaner trough water over dam water, but it is not available to all. Lardner et al (2005), in their study of cattle performance, showed that by improving water quality with pumping and aeration to a trough, weight gains of 9 – 10% were achieved over the control mob over a 90 day grazing period in most years.

Dry matter, grazing management and stock density – the numbers

Kirkegaard et al. (2016) expressed DM production in terms of dse days/ha. They write that "early-sown, slower-maturing crops have the longest vegetative period and provide the most grazing potential, but typical grain-only spring crop varieties can also be sown early and provide useful grazing without significant yield loss following the same principles – but the potential grazing is much reduced, and closer management of lock-up timing is required". Further, when it comes to planning, preparation and sowing (i.e. all key management activities), they quote that "each week delay in sowing wheat after early March, reduces grazing potential by 200-250 dse.days/ha and yield by 0.45 t/ha".

So, the challenge is to convert this DM into red meat as best we can, without penalising ourselves in grain yield. Again, I refer you to Kirkegaard et al. (2016) for a very explicit description of that critical time to destock, or "shut the gate" so that little or no grain penalty occurs. You will note that this decision is driven by the plant, through its stage of growth and critical residual biomass needs and not by a date on a calendar. If maximising grain yield is a key target, it is imperative to get this destocking decision right.

Understanding plant growth, time to first graze and regrowth rates enables us to predict how many stock, of what class, will be required during the season. In the late 2000's, working with a grower at Cumnock (Central West Slopes), we aimed to get 60 – 75 days grazing from the early sown cereals. This was usually achieved in two or three grazings but required good estimations of DM prior to and during grazing, and what growth rate could be expected during the 'rest or recovery period'. Figure 1 provides DM growth rates for the Central West Slopes (NSW DPI – Prograze, 2000), for a range of pastures species, with oats included as a reference. The oat growth curve line is 'indicative' of a cereal crop's daily growth rate (kg DM/ha/day) in this region, and while I accept that wheat may be slightly lower or it may be sown slightly later, it can be used to estimate a potential grazing situation. There are good data sets of DM rates available from more recent NSW DPI/GRDC trials should you wish to fine tune your future DM estimates for areas closer to home.

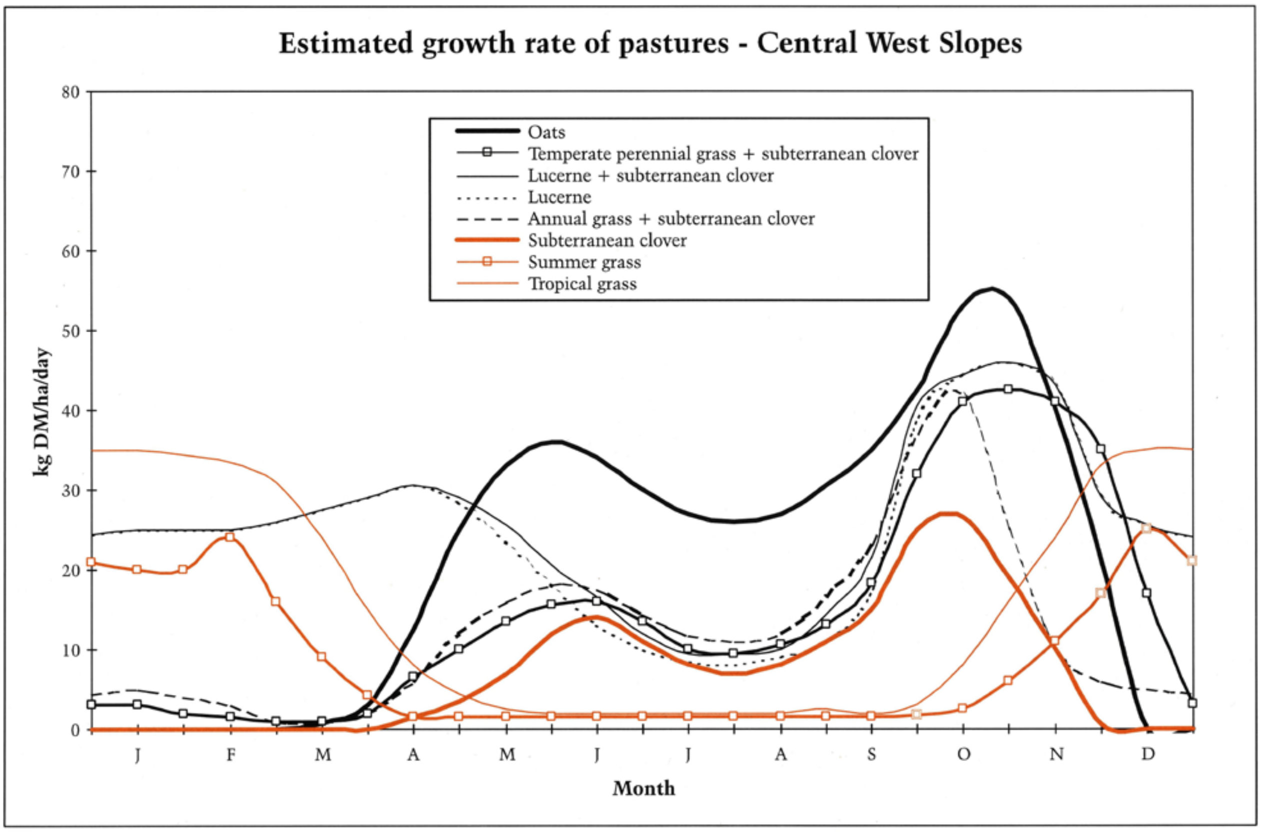

Figure 1. Estimated growth rate (kg Dry Matter/ha/day) of pasture species on the Central West Slopes of NSW (Source NSW DPI - Prograze)

By providing a working example of DM utilisation, it may make the following numbers more understandable. Using the oat growth rate line (the top thick black line from May to October) from Figure 1 as a guide (and knowledge of more recent wheat DM growth rates from various locations), one can estimate how much DM could be on hand by a certain point in the growth cycle. By sowing early (March 1) into a well prepared and planned paddock, one could estimate DM by mid-May to range from 1800–3000 kg DM/ha pending species/varieties/growing conditions. If sowing date was a month later (April 1st), this same DM is likely to be achieved by mid to late June. So how do we use it?

DM utilisation is the amount of DM consumed by the animal as a % of total on offer. For cereals, I estimate 60 – 70% utilisation pending row spacing, and I am aware of data showing higher utilisation rates in canola. The caution here is not to over-estimate potential DM on offer, as running out of crop DM is far worse than having more left in the paddock than first planned. It takes experience, and lots of it, as no two seasons are the same, and growth rates can change rapidly in response to dry spells, frosts and nutrient deficiencies to list a few. The second variable to consider before stocking is how much residual DM to aim for to enable speedy recovery/regrowth. Best regrowth occurs when there is 1000 – 1400 kg DM remaining (typically 10 – 12 cm high in cereals). Eating below this range restricts regrowth rates for a period, thus decreasing overall DM available for consumption during the season. As Kirkegaard et al. highlight, "not leaving enough residual biomass after the last grazing is very damaging in terms of grain recovery".

So, for the first grazing, if we average possible DM on hand (2400 kg/ha), and likewise average what residual DM we want left (1200 kg/ha), we can determine there to be 1200 kg DM/ha that we have available to eat. If this is consumed at 65% utilisation, then we eat 780 kg DM. Now the stock class and size and continued crop growth comes into play. Using a 35 kg lamb (0.8 dse), one estimates they will consume 3-4% of their body weight a day (1.05 – 1.4 kg DM/day, average 1.2 kg DM/day), while from figure 1, growth rate of the crop will continue at say 30 kg DM/day. So just to "hold" the crop where it is, one needs to eat the daily growth (30 kg DM @ 65% = 19.5 kg) which will require 16 lambs/ha. Should we wish to eat the available 780 kg DM over the next 3 weeks, then 780 kg DM /21 days = 37 kg DM/day is further required to be eaten. Again at 1.2 kg DM/day eaten by each lamb, this existing DM needs another 31 lambs/ha. Multiply this by grazable crop area, and this is where paddock size and water source(s) become critical to total stock number required. This above example indicates more than 45 lambs per ha (at a point in time) could be required to get the best grazing efficiency, and thus productivity and profit.

The balancing act of having this amount of quality feed on offer for an extended period means that usually three paddocks or areas of similar size will be required so a 21 day rotation as indicated in the above example can be practiced. This allows approximately 42 days between grazings, enough for significant DM growth if good grazing management principles are applied, and minimum DM limits obeyed.

Similar calculations can be run for grazing crop situations, it just requires DM estimates and predicted DM growth rates, keeping in mind that when the crops near 'lock up' time, these stock, if not ready for sale, need to go somewhere else! As noted earlier in this paper, additional gross margin returns of $600/ha are quite achievable in the current livestock market, with a significant range, pending crop season length, from $300/ha to more than $1000/ha.

References

Dept. Primary Industries and Regional Development, WA (2020) 'Water quality for livestock'.

Kirkegaard. J, Sprague. S, Lilley. J, and Bell. L (2016). Managing dual-purpose crops to optimise profit from grazing and grain yield. GRDC Grains Research Update, Coonabarabran. (https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2016/02/managing-dual-purpose-crops-to-optimise-profit-from-grazing-and-grain-yield)

Lardner. H.A, Kirychuk, B.D, Braul. L, Willms. W.D, and Yarotski. J, (2005). The effect of water quality on cattle performance on pasture. AJAR 56 (1) 97-104

NSW Agriculture and Meat & Livestock Australia (2000). Prograze, Profitable, sustainable grazing. ISBN 0 7347 1193 X

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Dual-purpose crops – direct and indirect contributions to profit

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Key words

grazing, livestock, whole-farm

GRDC code

CSP00160, P.PSH.1045 (MLA)

Take home messages

- Dual-purpose crops provide a good option for utilising early sowing opportunities (Feb-April) allowing diversification of income, reduced risk, flexibility of use and potential for higher returns than grain only crops
- Sowing early maximises the potential grain yield and grazing opportunity from dual-purpose crops
- Management to maximise grazing while mitigating yield losses is critical to maximising returns from dual-purpose crops
- Combinations of dual-purpose canola and wheat can provide large pasture spelling benefits and maximise winter feed supply
- Dual-purpose crops can allow changes to livestock enterprises (e.g. lambing date, stocking rate) that bring about benefits to animal health, reduced supplementary feeding and increased animal growth rates
- Whole-farm benefits can accrue to produce returns of >$1000 per ha of crop sown above those of grain-only crops in higher rainfall zones of southern NSW.

Introduction

Dual-purpose crops hold great potential to utilise early-season sowing opportunities to provide extra grazing for livestock and maintain grain yield. With good management, the period of grazing can increase net crop returns by up to $600/ha (i.e. 2000 sheep grazing days at 28c/day) and have a range of system benefits including widening sowing windows, reducing crop height, filling critical feed gaps and spelling pastures. Over ten years of experiments, simulation studies and collaborative on-farm validation across Australia has demonstrated that a wide range of cereal and canola varieties can be successfully grazed and recover to produce combined livestock and crop gross margins that exceed grain-only crops and increase whole-farm profitability (Table 1).

Table 1. Typical examples of forage, grain yield and gross margins achieved from well-managed dual-purpose crops by collaborating growers in southern NSW

Crop type	Grazing achieved (DSE.days/ha)	Grain yield (t/ha)	Paddock $GM increase above grain only
Winter wheat	1600 - 2700	4.5 – 6.5	+$600 - $1000
Spring wheat	400 - 800	3.0 - 5.0	+$300 - $500
Winter canola	750 - 2500	2.0 – 4.0	+$600 - $1000
Spring canola	300 - 700	1.5 – 2.5	+$300 - $500

In a review of 134 different grazing wheat experiments we found <10% returned less than grain only wheat crops, the median increase in net returns from grazing was 25% and in one third of cases, net returns increased by 75% or more. In the 87 canola grazing experiments returns were somewhat less (median 17%) due to less grazing, and higher grain-value and so increased economic risks from yield reductions (Figure 1).

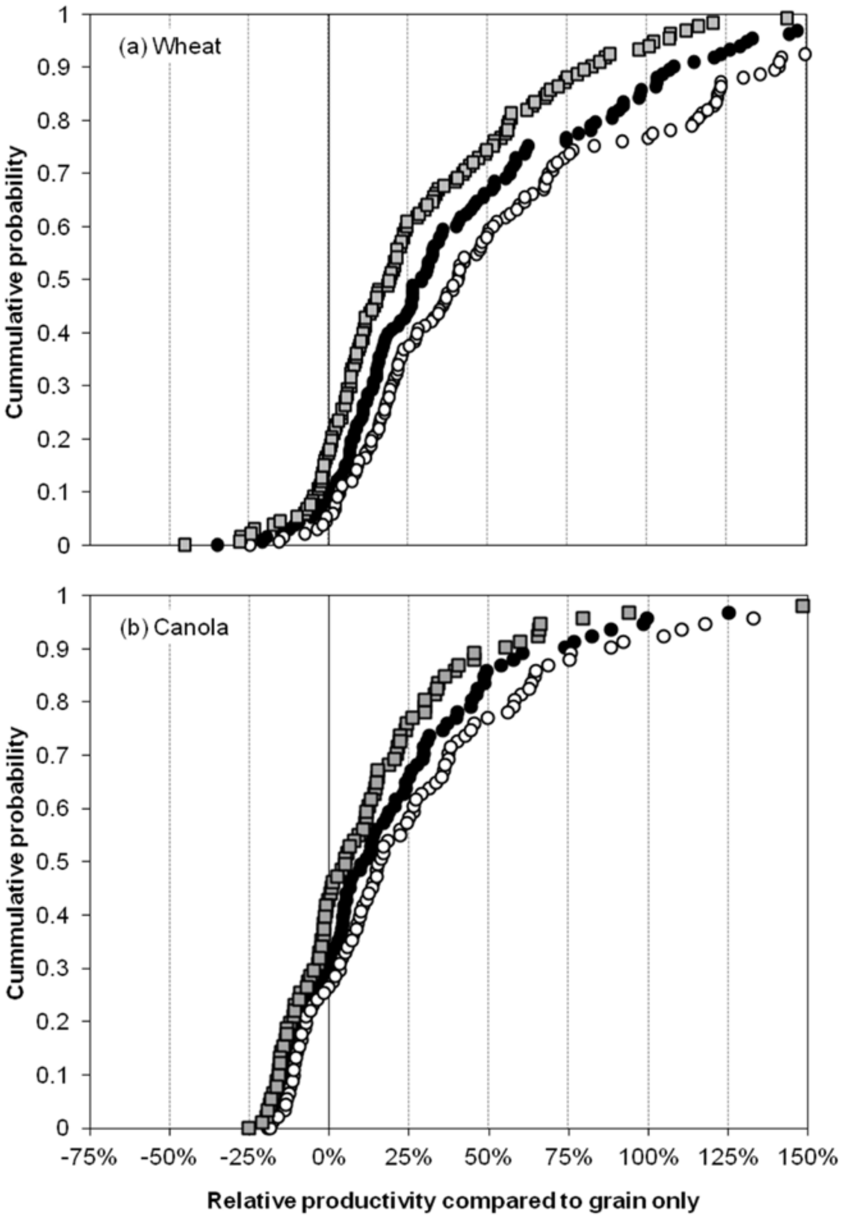

Figure 1. Analysis of relative estimated returns from grazed dual-purpose wheat (n=134) (a) and canola (n=87) (b) compared with grain only system across experiments where biomass for grazing (or grazing days) and subsequent grain yield was measured in Australia. The impact of different price ratios between livestock and grain (i.e. $/kg liveweight compared to $/kg grain) on total returns are shown when prices for livestock are relatively high (hollow circles; wheat – 10, canola – 5), average (filled circles; wheat – 8, canola – 4) and low (grey squares; wheat – 6, canola – 3). Livestock yield was estimated assuming a feed conversion rate of 0.17 kg LW/kg of forage consumed (based on data in Dove and McMullen, 2009) ; where available biomass only was measured 60% utilisation of this was assumed.

The greatest advantage of dual-purpose crops is when they are sown early to utilise early season sowing opportunities (e.g. before end of April). At this time the long-season winter cultivars provide high yield potential without the frost risk for sowing spring cultivars at that time, because the vernalisation in these cultivars control flowering to a time of year when risks are low. At the same time the earlier sowing of the varieties will yield much more grazing opportunities. After early May the dual-purpose varieties offer little advantage over the spring cultivars typically used for grain only production.

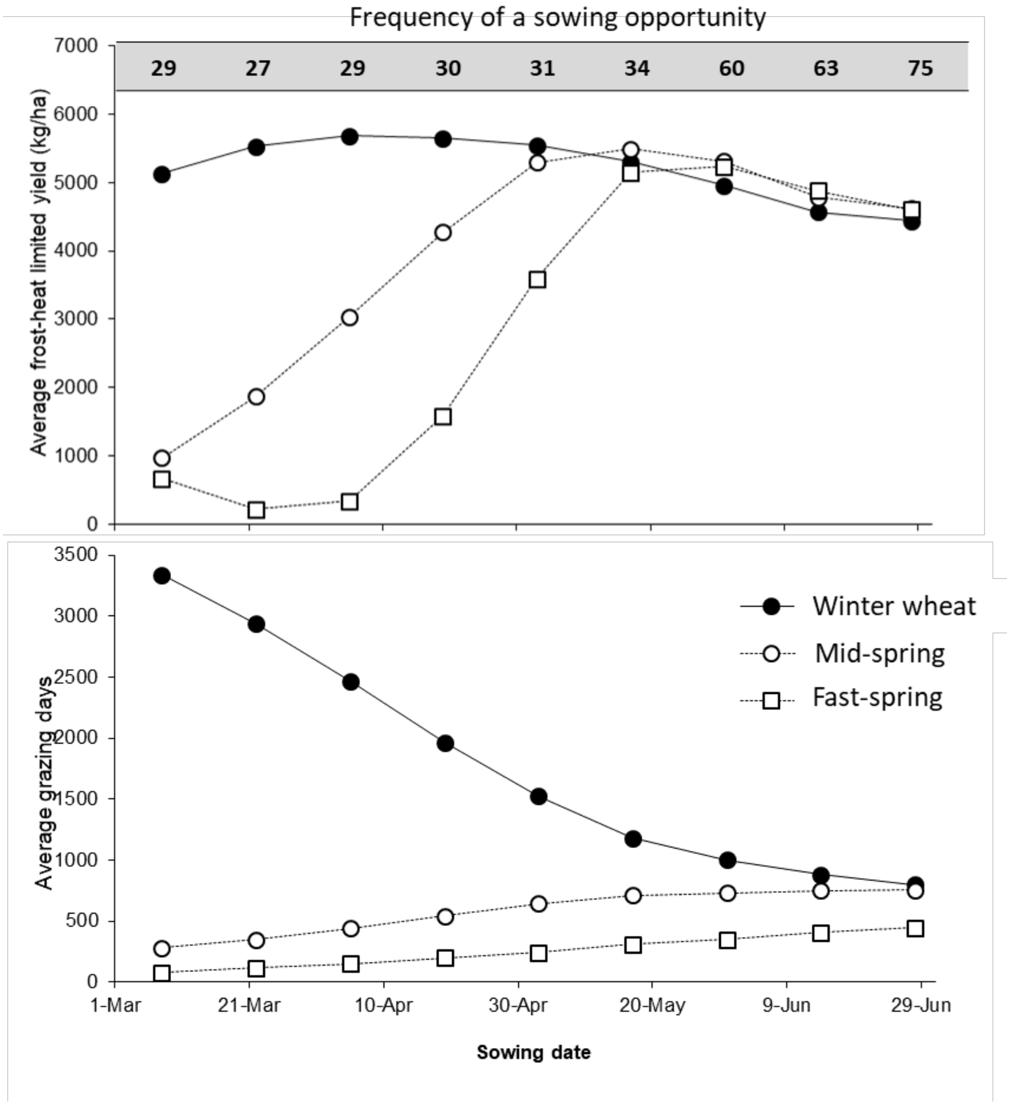

Figure 2. Simulated average grain yield and grazing potential from a dual-purpose winter wheat (e.g. EGA Wedgetail⍉) compared to mid and fast-spring grain wheats for different sowing times at Quirindi. The frequency of a sowing opportunity in each of these sowing windows is also predicted based on the proportion of years when rainfall exceeds potential evaporation over seven days in these fortnightly sowing windows.

Optimising economic returns – balancing grazing and grain value

Ultimately economics (feed value vs grain value) in the farm enterprise dictates the acceptable level of grain yield loss (if any) for dual-purpose crops. In many cases, especially where the feed is being used to fatten or finish lambs or cattle, it is possible that accepting a grain yield penalty makes the most economic sense, as shown for the moderately grazed crop shaded in Table 2. However, managing these potential trade-offs to optimise profit will be influenced by the relative value of grain or livestock feed in that season as well as your location.

Table 2. Amount of grazing achieved and grain yield from different grazing treatments in a crop of EGA Wedgetail⫽ at Greenethorpe in 2013. Income was highest with a small grain yield penalty as the extra grazing was more profitable than yield lost.

Lock-up time	Grazing intensity	Sheep grazing d/ha	Grain yield (t/ha)	Paddock $GM increase above ungrazed
Un-grazed	None	0	4.35	0
DC30 (safe)	Hard	1730	4.36	$653
DC32 (sensitive)	Moderate	2530	3.96	$853
DC32 (sensitive)	Hard	2730	3.28	$758

(Economics calculated at $250/t grain and grazing at $0.38/sheep grazing day (i.e. $1.7/kg LW for a sheep growing at 225g/day and eating 1.5 kg biomass/day)

Spring wheats such as EGA Gregory⫽ can also be grazed with success, but due to the later optimum sowing dates and smaller safe grazing window, the amount of grazing achieved is much less (Table 3). The effect of grazing too late and/or leaving too little residual biomass (<0.5 t/ha) can be seen to impact on the economic outcome. In this case with spring wheat, yield was only maintained with later grazing if a large amount of residual remained, and this did not match the economics of grazing hard earlier to provide time for recovery. In general, a much greater level of attention is needed to manage the timing of lock-up in spring crops as development is rapid and the plants less robust. But grazed spring wheat and canola crops can widen the crop-grazing window at the farm-scale.

Table 3. Amount of grazing achieved, grain yield and additional income from different grazing treatments in an EGA Gregory⫽ wheat crop at Greenethorpe in 2014. The best outcome was to graze safely with economic penalties for later or harder grazing.

Lock-up time	Grazing intensity (and residual t/ha)	Sheep grazing d/ha	Grain yield (t/ha)	Paddock $GM increase above ungrazed
Un-grazed	None	0	4.78	0
DC30 (safe)	Hard (0.5)	1070	4.68	$382
DC32 (sensitive)	Moderate (1.5)	800	4.85	$321
DC32 (sensitive)	Hard (0.6)	1390	3.94	$316
DC32 (unsafe)	Hard (0.4)	1520	3.65	$291

Implications for whole-farm profitability

Dual-purpose crops can provide valuable winter forage in livestock production systems and greatly reduce the frequency of feed gaps in winter and can allow higher winter stocking rates. By removing grazing pressure on pastures at this time they can also increase subsequent pasture availability. Using experimental measurements of sheep grazing on pasture only or dual-purpose crops of wheat, canola, and wheat and canola in combination, and their associated effects on subsequent pasture grazing, we estimated for two different years whole-farm changes in whole-farm sheep grazing days, relative farm production and farm economic impact. The increased winter feed supply and the higher grazing intensity on dual-purpose crops allowed 2-3 times the area of pasture to be spelled which together enables increases in potential year-round pasture stocking rate (Table 4).

Table 4. Measured and estimated details of grazing from pasture-only and systems incorporating dual-purpose wheat (Pwheat), canola (Pcanola) or both (Pcanola + wheat) during winter-spring monitoring period in 2010 (13 Apr-15 Dec) and 2011 (20 Apr-10 Nov) (see Dove et al. 2014).

	Pasture-only	Pwheat	Pcanola	Pcanola+wheat
2010 - 246 days				
Pasture grazing days/ha	3851			
Crop grazing days/ha		2393	2095	1723^
Extra pasture grazing following crop		347	810	2338
Days grazing crop (d)		69	62	91
Crop stocking density (DSE/ha)		34.7	33.8	37.9
Pasture stocking rate (DSE/ha)	15.7			
Crop grain yield (t/ha)		5.0	1.9	
2011 – 204 days				
Pasture grazing days/ha	2944			
Crop grazing days/ha		1455	735	1037^
Extra pasture grazing following crop		0	118	472
Days grazing crop (d)		30	18	43
Crop stocking density (DSE/ha)		48.5	40.8	48.2
Pasture stocking rate (DSE/ha)	14.4			
Crop grain yield (t/ha)		5.4	3.6	

^Combined crop grazing on Pcanola+wheat measured experimentally were obtained from twice the crop area (i.e. two experimental plots) and hence were halved to calculate on a per crop hectare basis.

Up to 20% of farm area could be allocated to dual-purpose crops while still obtaining the same number of grazing days per farm hectare, with the benefit of additional grain production (5.0-5.4 t wheat/ha and 1.9-3.6 t canola/ha) adding significantly to farm profitability and production. Allocating 10-20% of the farm to a combination of dual-purpose wheat and canola grazed in sequence, could increase whole-farm sheep grazing days by 10-15%, increase farm output by >25% and increase estimated farm profit margin by more than $150/farm ha compared to pasture-only livestock systems (Figure 3). The long crop grazing period from using both dual purpose wheat and canola in combination, providing a large pasture spelling benefit was a key factor enabling these economic and productivity increases. Introducing wheat or canola alone on up to 30% of the farm is likely to reduce sheep grazing days/farm ha, but still significantly increase whole-farm productivity (10-20%) and estimated profit margin ($50-100/farm ha).

Over the two very different experimental growing seasons, the estimated relative changes in whole-farm productivity and estimated profit margin were similar, indicating that these benefits are likely to be consistent over a range of years. Similarly, price sensitivity analysis also shows that these results are robust under a range of prices for livestock and grain (Table 5). Together these findings suggest that once whole-farm livestock feed-base effects are considered, large economic and productivity benefits can be attributed to dual-purpose crops when integrated into livestock production systems in Australia's southern high rainfall zone.

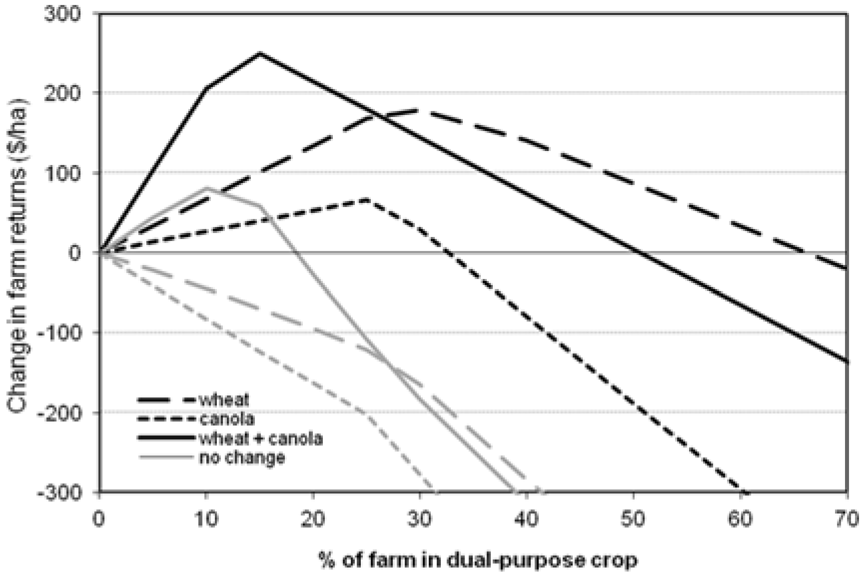

Figure 3. Change in estimated farm profit margin over two experimental years (2010 and 2011) with increasing area of farm removed from permanent pasture and sown to a dual-purpose crop: wheat alone (long dashes); canola alone (short dashes); and 1:1 wheat and canola in combination (solid line). Prices for grain and livestock grazing were: Wheat = $220/t, canola = $450/t, $0.15/sheep grazing.day.

Table 5. Sensitivity of changes in estimated farm profit margin to 20% higher and 20% lower grain and livestock prices when 20% of the farm has been allocated to dual-purpose crops (average of both experimental years).

	Wheat only	**Canola only**	**Wheat + canola**
Standard prices	+37	+36	+199
High grain price	+81	+81	+248
Low grain price	-7	-9	+150
High livestock price	+26	+28	+218
Low livestock price	+48	+44	+177

Interactions with livestock system

Changes to the livestock enterprise to capitalise on the additional winter feed supply can also bring about further gains from dual-purpose crops. Analysis conducted by Shawn McGrath in southern NSW, shows that shifting lambing from spring (August) to autumn (May) can increase lamb production and farm gross margin (Table 6). This is further improved when this is combined with higher stocking rates which make better use of this winter feed source. For example, increasing stocking rate by 25% (e.g. from 6 to 8 ewes/ha) the increase in gross margin from incorporating the dual-purpose crop was 67%, supplementary feeding was dramatically reduced, and lamb production and likelihood of meeting premium market specification increased. This clearly demonstrates that dual-purpose crops can allow significant changes in the livestock enterprise while reducing risk and increasing productivity and profitability.

Table 6. Effect of varying lambing month and stocking rate on lamb production, grain supplements fed and gross margin from incorporating dual-purpose crops into the farm feedbase (adapted from McGrath et al. 2014).

Lambing month	**Stocking rate (ewes/ha)**	**% change in GM ($/ha)**	**Change in supplement grain fed (kg/ha)**	**Change in lamb production (kg/ha)**	**Change in % of years lambs reach > 39 kg at sale**
May	6	11	-86	+12	+2
	8	67	-155	+45	+10
	10	241	-260	+80	+22
August	6	8	-84	+5	0
	8	21	-172	+12	0
	10	56	-285	+17	+5

Animal health

The introduction of a dual-purpose crop offers some opportunities for disease prevention in the livestock enterprise. Often, young animals are the most susceptible to disease risks, particularly as they transition from milk feeding to grazing. Gastrointestinal parasites, blow fly strike (*cutaneous myiasis*) and skin-penetrating grass seeds are all threats to recently weaned lambs. Spring lambing with weaning onto pastures in late summer and autumn leaves animals exposed to all three threats, particularly in northern NSW. In these areas, the summer/autumn period is risky for Barber's pole worm (*Haemonchus contortus*), the most pathogenic of the major gastrointestinal parasites, blow fly strike, and damage from particular perennial grass seeds. The filling of the winter feed gap with dual-purpose crops provides the opportunity to shift lambing dates earlier and hence mitigate some of these animal health risks.

Simulations of the risk of flystrike over a 30-year period was much higher when the lambs were born in late-winter/spring (September) than in late-autumn (May) by a factor of 6 to 15 (Table 7). A longer period lambs spent on farm before sale due to lower growth rates, always increased the incidence of flystrike. Late-winter/spring born lambs on a property with an average risk of flystrike would require preventive treatment, with the cost depending on the time of sale. Lambs born in May might not require preventive treatment, unless growth was slow resulting in their sale later than October. The net benefit from dual-purpose crops allowing a shift in lambing date and higher winter growth rates is likely to be in the order of $1.0-1.5/lamb. We expect similar results for reducing worm burdens but analysis and quantification of the scale of this benefit is ongoing.

Table 7. Comparison of autumn vs spring lambing under high and moderate lamb growth rates on average flystrike incidence (number of lambs) and costs ($) per lamb weaned over a 30-year period (1988-2018).

Lambing time	**Lamb growth rate (kg/d)**	**Predicted sale date**	**% Strike when untreated**	**% Strike when Treated**	**Strike treatment Costs per lamb**
Autumn (23 May)	0.25	30 Oct	2.1	2.1	$0.54
	0.20	9 Dec	8.7	1.4	$1.13
Spring (8 Sep)	0.25	15 Feb	31.2	2.5	$1.60
	0.20	27 Mar	49.6	1.8	$2.00

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References

Dove H, Kirkegaard JA, Kelman WM, Sprague SJ, McDonald SE, Graham JM (2015) Integrating dual-purpose wheat and canola into high-rainfall livestock systems in south-eastern Australia. 2. Pasture and livestock production. Crop & Pasture Science 66, 377–389.

McGrath SR, Virgona JM, Friend MA (2014) Modelling the effect of stocking rate and lamb production of allowing ewes to graze a dual-purpose wheat crop in southern NSW. Animal Production Science 54, 1625-1630.

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Pros and cons of grazing crops east of the Newell

Ed Blackburn, Cudgegong Rural Supplies, Mudgee

Key words

grazing crops, dual purpose, ground cover, risk, weeds, disease, profit

Introduction

The grazing of cropping paddocks be it in a 'dual purpose' scenario or in an attempt to capture value from a failing grain crop raises a number of questions and options for potential costs and benefits - many of which are difficult to quantify.

Many benefits are direct and tangible in the current time, realised in the form of prime animals and healthy trading margins, while many of the potential costs, can impact the business for some years – particularly if practices are not well executed. The aim here is to begin to discuss both the costs and benefits to a cropping enterprise of allowing stock to graze crops. The points raised below are certainly not an exhaustive list of what needs to be considered.

Table 1. Pros and cons of grazing crops and stubbles

Pro's	Con's
Cash flow generated from the paddock is positive prior to grain harvest. (See Table 3. 2019 Myall paddock case study)	In dry years with no crop emergence - what can you do to provide an alternate feed source for stock!
Multiple income streams can be generated such as stock, grain, agistment, profit share, stock trading etc	Negative effect on fallow efficiency resulting from reduced groundcover
Can generate returns even in a bad year (see Table 3)	Increased soil compaction from animal traffic– severity varies by soil type
Takes early season and post-harvest stocking pressure off pasture country	Need to actively manage grazing intensity to maintain minimum biomass and remove stock at recommended crop growth stages to prevent potential grain yield penalties.
Control weed blowouts – spray out then graze out	Greater opportunity for weeds to emerge in-crop once pre-emergent herbicides control declines and may result in additional in crop management requirements
Flexibility in rotations (i.e. not locked in at any stage of the season. If the season turns sour options are there for hay cut or graze out. Even if the crop is initially locked up for grain you can change your mind)	Can complicate rotation planning and encourage bad habits (i.e. temptation towards more cereals, less break crops)
Options to dry sow dual purpose crops increases the opportunity for germinating rain events – big in 2019.	Removal of crop canopy in mid-winter with grazing can give weeds a second chance to establish.

The case study information presented in Tables 2 and 3 are provided to demonstrate the financial benefits that dual crops can provide to mixed cropping enterprises.

Table 2. 2019 Myall paddock case study - 36ha. EGA Wedgetail ⊕ wheat.

Stocking for the crop
16/5-20/5 (4 days) - 111 steers (av 290 kg on) = 444 steer days
20/5-19/6 (30 days) - 129 steers (av 290 kg on) = 3870 steer days
27/6-24/7 (27 days) - 56 steers (400 kg on) = 1512 steer days
5/9-27/10 (52 days) - 44 cows and calves (C&C) = 1.22 C&C/ha for 52 days
Income (without considering appreciation between buy and sell price)
1 - Steer grazing - 162 steer days per hectare @ 1.6 kg/hd/day ADG (actual) and $3.30/kg (actual) = $855.36/ha from steer grazing
(Note that's straight out $/kg for the kg put on, not including the appreciation of buying at $2.80 and selling at $3.30.)
2 - Cow & calf grazing - 1.22 units/ha x 52 = 63.44 C&C days/ha @ $2/day = $127/ha
Total = $982.24/ha gross income
Income (considering appreciation between buy and sell price)
1) 80 steers purchased at $2.80/kg and 285 kg empty = $800. Sold at $3.30/kg and 392kg empty = $1293.6 after 70 days for a margin of $493/hd. The paddock ran in effect 2.22 steers per hectare for the 70 days x $493/hd trades per hectare = $1094/ha trade margin or gross income per hectare
(The paddock ran in effect 2.22 steers per hectare for the 70 days, and as such facilitated 2.22 trades per hectare x $493/hd trades per hectare equals $1094 trade margin or gross income per hectare)
2 – Cow & calf grazing - 1.22units/ha x 52 = 63.44 C&C days/ha @ $2/day = $127/ha
Total = $1221/ha gross income
Notes
Crop was dry sown on 22nd March in front of rain While it was intended for dual purpose, due to the dry season it ended up grazed out
Was locked up 24th August, before being opened back up to stock early September
Sown at 55 kg/ha seed with MAP fertiliser at 80 kg/ha
Broadleaf spray of 1L/ha 420 g/L MCPA and 26 g/L picloram, 25g/ha Paradigm® and 500mL/100L Uptake® on the early May.
Rotationally grazed and stock given access to Causmag® and salt mix ad-lib in troughs
Minimal in-crop rainfall - one good 24mm fall on 4th May was practically it.

Table 3. Winter wheat vs main season wheat gross margin

WINTER WHEAT			MAIN SEASON WHEAT		
COSTS			COSTS		
Timing	Activity	Cost $/ha	Timing	Activity	Cost $/ha
1st Dec	Fallow spray one	$20.00	1st Dec	Fallow spray one	$20.00
1st Feb	Fallow spray two	$20.00	1st Feb	Fallow spray two	$20.00
1st Apr	Knockdown spray	$19.00	1st Apr	Fallow spray three	$20.00
	Sowing	$40.00	1st Jun	Knockdown spray	$19.00
	Seed cost @50kg/ha	$21.50		Sowing	$40.00
	Starter fertiliser cost	$56.00		Seed cost @50kg/ha	$21.50
2nd Apr	Logran® spray	$10.00		Starter fertiliser cost	$56.00
1st Jun	Top dress urea @ 150kg/ha	$90.00	2nd Jun	Logran spray	$10.00
15th Jun	In crop broadleaf spray	$35.50	1st Aug	In crop broadleaf spray	$35.50
1st Sep	Foliar fungicide	$12.25	15th Aug	Top dress urea @ 125kg/ha	$77.00
15th Dec	Harvest @ $17/t	$40.80	15th Dec	Harvest @ $17/t	$68.00
Total Costs		**$365.05**	**Total Costs**		**$387.00**
INCOME			INCOME		
15 May-15 Jun	1st graze	$290.63		grain (4t @ $300/t)	$1200.00
15 Jul-15 Aug	2nd graze	$290.63			
	grain (2.4t @ $300/t)	$720.00			
Total income		**$1301.25**	**Total income**		**$1200.00**
Position day before harvest		**$257.00**	**Position day before harvest**		**-$319.00**
Gross margin (income - costs)		**$936.20**	**Gross margin (income - costs)**		**$813.00**
ASSUMPTIONS					
Grower retained seed - $60/t grading cost, Hombre® Ultra treated, $300/t grain value on farm					
Croplift® 15 as starter applied @ 80kg/ha @ $700/t					
Urea is worth $550/t					
Contract spraying ($8/ha) sowing ($40/ha) and harvesting ($17/ha), urea spreading $8/ha					
Fallow sprays all 1.25L glyphosate (540 gai/L) ($7.50/L) and tank-mix partner ($9/L), at 8-week intervals					
Post sow/Pre-em Logran ($2), In crop broadleaf spray 1.5L, Precept® ($27.50)					
Livestock gain 1.25kg/hd/day, cattle worth $3/kg into feedlot					
Stocking rate of 2.5 steers per hectare for 60 days of the 90 days of winter					
Grazed 15/5 for a month, spelled 15/6 for a month, grazed 15/7 for a month, locked up 15/8					
Grain (H2) is worth $300/t on farm					

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Pros and cons of grazing crops west of the Newell

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Notes

Lasers, machine learning, weed recognition and new innovations in weed management

Guy Coleman, Caleb Squires and Michael Walsh (University of Sydney)

Key words

machine learning, laser weeding, weed control, site-specific weed management

GRDC code

US00084

Take home messages

- Advancements in machine learning, particularly deep learning, are creating opportunities to use non-selective alternative weed control options
- Following a comparison of energy requirements lasers were identified as the most suitable alternative option for further research and development.

Site-specific weed control

The widespread development of herbicide resistance across the northern region and around Australia is driving the need to develop alternative weed management options. The selectivity of several alternatives is linked with their method of application.

Some non-selective alternatives, such as flame weeders may be used inter-row, while commercial broadacre electrical weeders use height to differentiate weeds from crop. Outside of these commercially available implements, most alternatives to herbicides are often more costly, not yet commercialised, lacking research or not sufficiently effective for broadacre cropping.

Machine learning-based weed identification can provide the detection and identification of weeds in the crop using algorithms based on convolutional neural network (CNN) architectures. These can provide the opportunity to use non-selective physical and thermal weed control options for the control of in-crop weeds. Since the demonstration of CNNs as highly accurate for image classification tasks in Krizhevsky et al. (2012), there has been significant advancements such that CNNs may now be used to accurately recognise individual plants, and potentially even the growing points of in-crop weeds. Machine learning-based weed identification enables selectivity on the delivery side of the control. This greatly increases the opportunity to develop previously unviable alternative control options as effective broadacre techniques.

While the opportunities clearly exist, the development of algorithms with consistently high accuracy and precision for use across the grain production region in Australia remains an issue. Recently, companies such as Bilberry (partnering with AgriFac) and now Autoweed are delivering some of the first commercially available camera and CNN-driven site-specific weed control sprayers. Simpler yet highly effective optical-driven camera sprayers such as Weedit® and WeedSeeker® have been in widespread commercial use for the selective control of weeds in fallow throughout the grain growing areas of northern NSW and Qld for many years. Detection-based delivery of herbicide coupled with the ability to differentiate weeds from crop is an important advancement and potentially a weed control game changer when perfected. However, at this stage the level of precision is lower than that needed for delivery of highly targeted alternative control methods.

Four different levels of weed detection (and identification) are currently achievable with state-of-the-art algorithms (Figure 1). The lowest granularity is image classification, which takes an image and provides a probability that the object (and others) exists in that image.

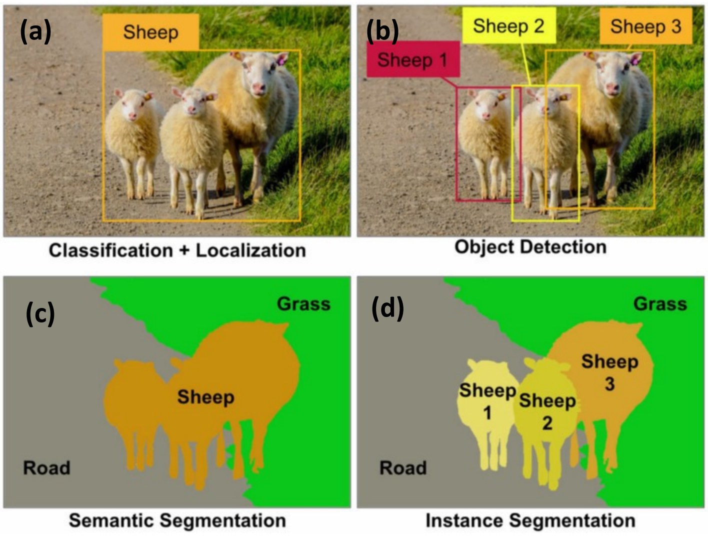

Figure 1. The four levels of object detection, localisation and discrimination from other objects of the same class. Each requires different algorithms and computational performance (Parmar, 2018).

The next level of discrimination is object detection. Object detection algorithms provide information on the number and general location of an object in the image (Figure 1b). Segmentation is the most granular, where every pixel in an image receives a classification (Figure 1c and 1d). Segmentation algorithms provide the level of detection required for delivery of highly targeted alternative control options to individual plants and plant parts, precision beyond the capabilities of current see and spray technology. At the object detection level, the Weed Research Team at the University of Sydney recently demonstrated the capabilities of existing object detection architectures (Figure 2) in differentiating annual ryegrass and wheat. While the demonstration used controlled growing environments and data for algorithm training, a key finding was that a lack of labelled data to train existing algorithms is the main barrier in developing detection algorithms of all four levels.

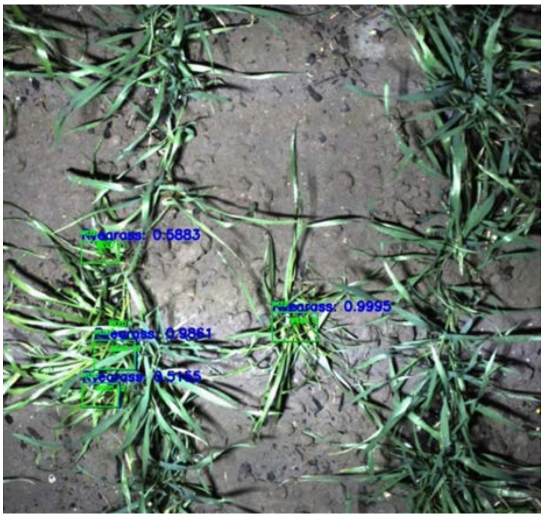

Figure 2. Initial testing of ryegrass detection in wheat has shown that existing machine learning architectures including You Only Look Once (YOLO) and Single Shot Detectors (SSD) are capable of differentiating ryegrass in wheat under controlled circumstances. This demonstration suggested lack of labelled data is the main barrier to development instead of technological advancement.

Moving from broadcast to site-specific application shifts the input and cost function of weed control from area-driven to a function of weed density, where the treatment is applied only where it is needed. Importantly, move to site-specificity creates a significant opportunity for cost and input savings, with potential for additional benefits in reduced off target and environmental impacts. It also opens up the possibility of alternative options such as lasers, electrocution and microwaves for practical use in broadacre crop systems.

Based on research comparing the energy consumption of alternative control methods by Coleman et al. (2019), lasers were identified as a potentially viable alternative weed control method. With relatively low power consumption, small size and ease of control, lasers (specifically diode and fibre) were seen as a potentially viable option for weed control. While the method of laser beam generation may differ (be it diode, fibre or CO_2 as a few examples), the fundamental control method is through the highly targeted and concentrated delivery of energy in the laser beam. Similar to other thermal methods, this energy heats plant cells to the point of rupture and death, however, rather than moving an implement, tine, microwave, flame or electrode to the weed, lenses and optics are used to direct and focus the beam from a distance. The energy is also highly targeted, with minimal loss in the process of delivery. The beam width, and hence the density of energy in the beam, can also be varied to treat a larger area. These practicalities of lasers, in comparison with the other control options available, made them a good choice for preliminary assessments.

Aims

With research and development occurring in the weed detection and identification space, there is a requirement for the identification and evaluation of alternative weed control options to couple with new detection technology. The aims of this research are two-fold:

1. Evaluate the efficacy of lasers for the control of winter and summer weeds
2. Identify laser parameters (type, setup and use) required to deliver effective weed control.

Laser weeding

During the 2019 winter season, pot trials on the efficacy of a 25 W, 1064 nm continuous wave diode laser were conducted on representative broadleaf and grass weeds relevant to the northern region, namely turnip weed (*Rapistrum rugosum*) and annual ryegrass (*Lolium rigidum*). The trials evaluated the effect of laser treatment duration, laser beam width (spot size), weed species and weed growth stage on weed control efficacy.

Treatment duration

Using a 5 mm diameter spot size, 60 second treatment times provided 100% control of two and six leaf ryegrass and turnip weed plants (Figure 3). In the two-leaf plants, the 2 second treatment provided control of the turnip weed, but did not control the ryegrass. These results suggest the subsoil growing point of many grass species may protect the plant from lower energy laser treatments. While the treatment time is long for a 25 W laser at 5 mm spot size (1.3 J/s mm^2), increasing the laser power increases the rate of energy delivery, reducing the treatment time required to deliver an equivalent dose. Where control was not provided, significant reductions were seen in weed biomass in mid-tillering ryegrass.

Laser beam width

While duration of laser treatment changes the total amount of energy delivered, adjusting beam width impacts on the intensity of energy applied to the plant. The intensity of the beam, which is determined by power per unit area or energy density, changes the properties from heating (low intensity) to cutting (high intensity). The 25 W laser was tested with 2, 5 and 10 mm spot widths, providing 8.0, 1.3 and 0.3 J/s mm^2 energy intensities. Larger spot sizes reduce the precision required for the targeting and detection system, however, the less intense energy means the treatment duration must be longer or the plant may not heat enough for cell death.

Two-Leaf **Four to Six Leaf**

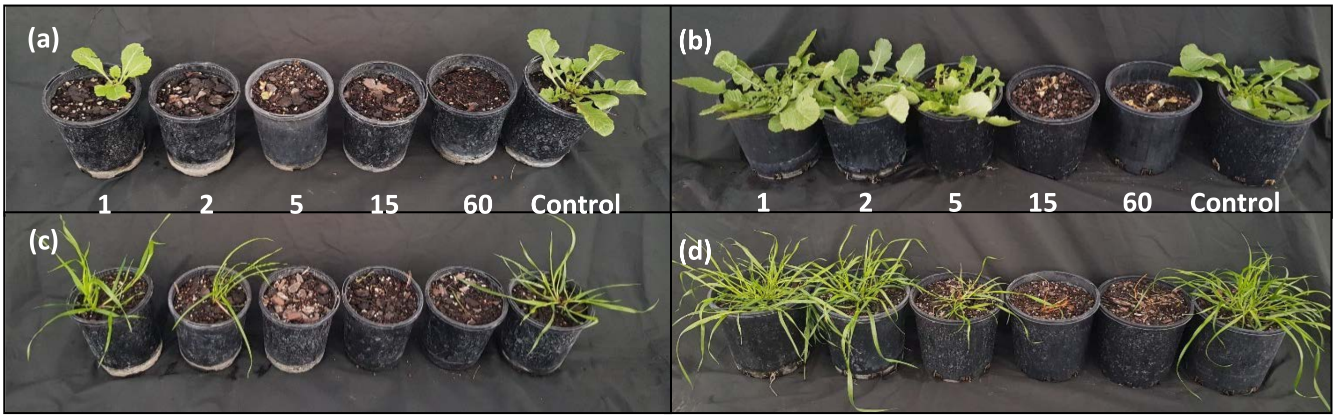

Figure 3. The impact of laser treatment duration at three weeks post treatment from left to right 1, 2, 5, 15, 60 second exposure and control (0) for turnip weed when treated at the two leaf (a) and four to six leaf (b) stage and ryegrass at the two leaf (c) and four to six leaf stages (d). Biomass was assessed three weeks post treatment.

At the two-leaf stage, there was a high level of control across all spot sizes for both turnip weed and ryegrass. At the four to six-leaf stage (Figure 4), the biomass reduction of turnip weed increased with increasing energy density (smaller beam width or higher intensity). Ryegrass was not significantly impacted. Using equivalent energy densities, it is estimated a laser of at least 400 W would be required to control four to six leaf stage weeds (including annual ryegrass) under 1 second treatment at a 5 mm beam width.

Future research on lasers will continue to evaluate the temperature thresholds required for control the growing point. A larger laser is expected to be used to assess the impact of the rate of energy delivery on control efficacy. Summer weeds will be tested in March 2020.

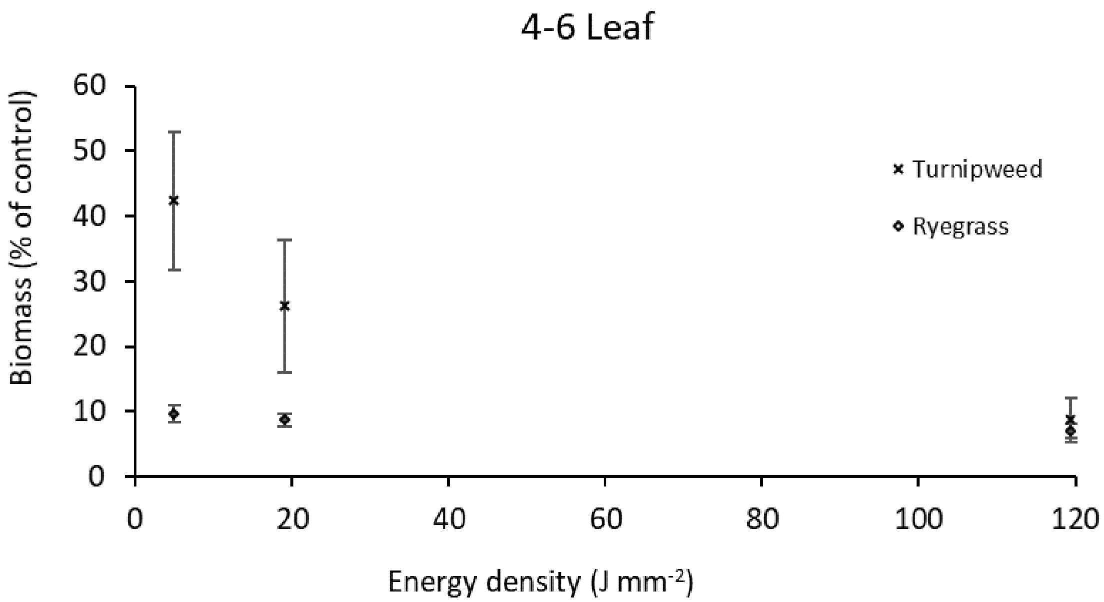

Figure 4. Comparing the impact of energy density (spot size) on plant growth behaviour as a percentage of the biomass of the control. Weeds were treated for 15 seconds using the 25W, 1064 nm diode laser.

Conclusion

Weed recognition through machine learning has the potential to enable alternative physical and thermal weed management options not previously considered relevant in broadacre agriculture. When applied on a site-specific basis, the energy costs of thermal control technologies such as lasers and electrocution are significantly reduced. Furthermore, lasers are showing promise as a highly targeted method for control of up to eight-leaf growth stage weeds. Yet even with such opportunity, the delivery of these technologies relies on highly accurate, precise and repeatable weed detection. Training state-of-the-art machine learning algorithms requires significant quantities of labelled image data obtained in diverse field conditions. Thus, a high-quality database of labelled images which reflects the diversity in Australian weeds, crops, and conditions is a pre-requisite and limiting factor for development of accurate weed recognition algorithms.

Concurrent with the development of detection capability, investigation of alternative weed control methods should be completed to determine relevancy and other optimal parameters for use. Initial research has shown that the potential for lasers is high due to the ability to flexibly deliver highly targeted energy, with positive results in both ryegrass and turnip weed.

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References

Coleman GRY, Stead A, Rigter MP, Xu Z, Johnson D, Brooker GM, Sukkarieh S and Walsh MJ (2019) Using energy requirements to compare the suitability of alternative methods for broadcast and site-specific weed control. Weed Technol 33:633–650

Krizhevsky A, Sutskever I and Hinton GE (2012) Imagenet classification with deep convolutional neural networks. Adv Neural Inf Process Syst:1097–1105

Llewellyn R, Ronning D, Clarke M, Mayfield A, Walker S, Ouzman J, Llewellyn R and Mayfield A (2016) Impact of weeds in Australian grain production: the cost of weeds to Australian grain growers and the adoption of weed management and tillage practices. CSIRO, Australia.

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Herbicide approvals: They can be relied on!

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Key words

pesticide regulation, APVMA, safety

Take home messages

- The Australian Pesticides and Veterinary Medicines Authority (APVMA) undertakes a comprehensive risk assessment of all pesticide products prior to registration, addressing risks associated with the product when used according to label directions
- The APVMA also keeps abreast of the developing science and world developments in both science and regulation to ensure that all pesticides are safe.

All pesticides are assessed by the APVMA prior to approval of actives and registration of products. This assessment is risk based, considering both the intrinsic hazard of the pesticide as well as the likely exposure resulting from their use, and is based on internationally accepted guidance. Australian evaluations are consistent with those carried out by other major regulators, as well as international organisations such as the Organisation for Economic Cooperation and Development (OECD), the World Health Organisation (WHO) and the Food and Agriculture Organisation (FAO).

While the APVMA can build on assessments carried out by other regulators and trading partners, such as the EU and the USA, many pesticides are approved in Australia prior to approval elsewhere in the world, and in these cases, other regulators may be utilising the Australian assessment as part of their own considerations. The rigor of the Australian assessment provides confidence that products registered in Australia are fit for purpose and are safe when used according to the label instructions. They are safe for the people who apply them, and for the environment in which they are used. Food crops treated with registered products are safe to eat, and for international sale, provided the label instructions are followed. APVMA also assesses that pesticides will meet label claims and will do the job needed.

The APVMA plays a key role in the National Registration Scheme, and, together with the states and territories, who have responsibility for the control of use of pesticides as well as ensuring compliance with label instructions, ensures that approved herbicides, insecticides and other pesticides can be relied on by users.

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Discussion forum - Q & A dealing with the drought and planning for recovery

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