NYNGAN
NEW SOUTH WALES
THURSDAY 27
FEBRUARY 2020

GRAINS RESEARCH UPDATE

DRIVING PROFIT THROUGH RESEARCH

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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

GRDC Grains Research Update
NYNGAN

Thursday 27 February 2020

Nyngan RSL & Civic Club, Pangee St, Nyngan

Registration: 8:30am for a 9am start, finish 3:00pm

AGENDA Time	Topic	Speaker(s)
9:00 AM	**GRDC welcome**	
9:10 AM	**Herbicide approval processes** - they can be relied on!	Jason Lutze/Sheila Logan (APVMA)
9:40 AM	**Farming systems and crop sequencing** - what have we learnt in 5 years of systems research? Nutrition, disease, yield and GM$	Greg Brooke (NSW DPI)
10:15 AM	**Integrating livestock into cropping systems using dual purpose crops -** getting the best out of grazed crops. Crop type, agronomy varieties, nutrition and time of sowing	Peter Matthews (NSW DPI)
10:45 AM	**Morning tea**	
11:15 AM	**Nutritional strategies to support the farming system -** P timing, placement and implications for N timing, rate and placement. Managing N - N movement, location, timing and budgeting. Recovery efficiencies - why are they so low and how does this affect strategy for use of our single largest input cost?	Mike Bell (UQ)
11:45 AM	**What's N doing in 2020 after 3 dry years with minimal mineralisation -** soil tests and farming systems trials	Discussion session led by Jim Laycock (Incitec Pivot) and Maurie Street (GOA)
12:20 PM	**Cereal pathology after the drought** - evaluating risk after crop and pasture; what's new (seed treatments), Predicta® B for in-crop diagnostics and options for high risk paddocks	Steven Simpfendorfer (NSW DPI)
12:50 PM	**Lunch**	
1:50 PM	**Matching varieties to time of sowing and situation** - what varieties perform on wide sowing windows and why? Issues for dry sown crops	Greg Brooke (NSW DPI)
2:20 PM	**Dealing with the drought and planning for recovery**	Discussion led by Maurie Street (GOA), Penny Heuston (Heuston Agronomy Services), Jim Laycock (Incitec Pivot) and Breil Jackson (Bogan River Downs)
3:00 PM	**Close**	

Contents

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Any research with unregistered pesticides or unregistered products reported in this document does not constitute a recommendation for that particular use by the authors, the authors' organisations or the management committee. All pesticide applications must be in accord with the currently registered label for that particular pesticide, crop, pest, use pattern and region.

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Herbicide approvals: They can be relied on!

Jason Lutze[1] and Sheila Logan[2]

[1] Executive Director Risk Assessment Capability
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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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Nitrogen and water dynamics in farming systems – multi-year impact of crop sequences

Andrew Erbacher[1]*, Jayne Gentry*[1]*, Lindsay Bell*[2]*, David Lawrence*[1]*, Jon Baird*[3]*, Mat Dunn*[3]*,*
Darren Aisthorpe[1] *and Greg Brooke*[3]

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Key words

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

GRDC code

DAQ00192, CSA00050

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.

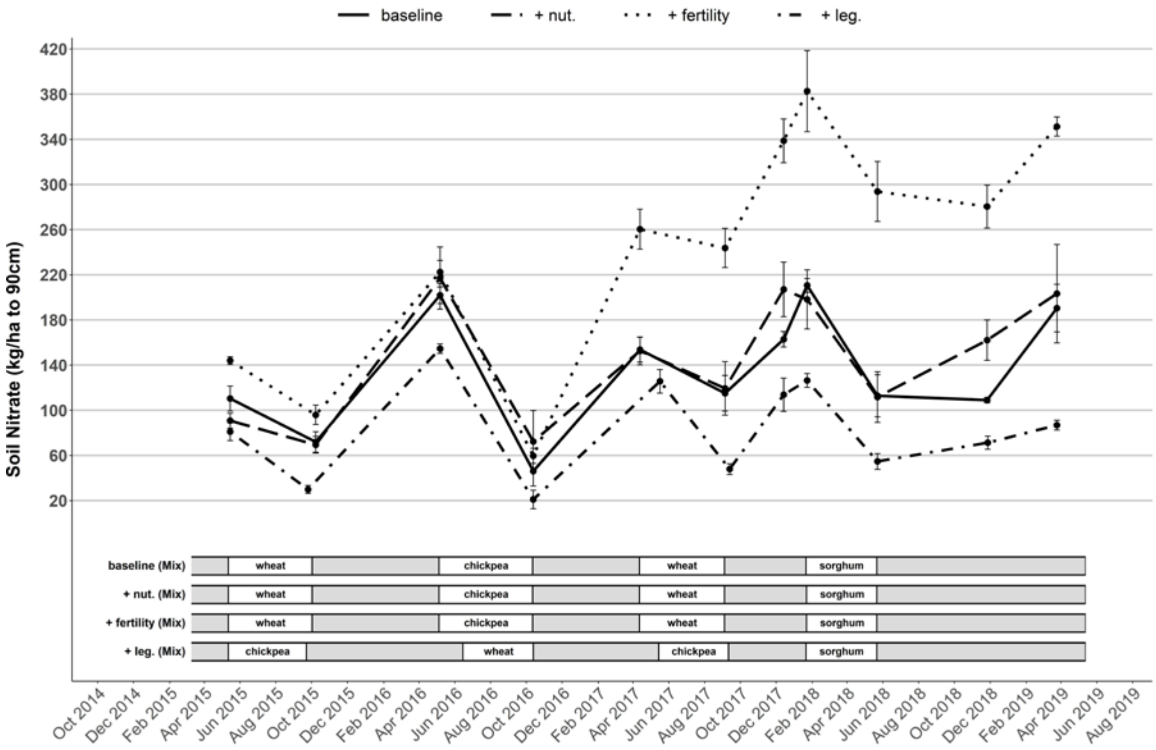

Figure 1. Dynamics of measured plant available soil nitrogen – Emerald.

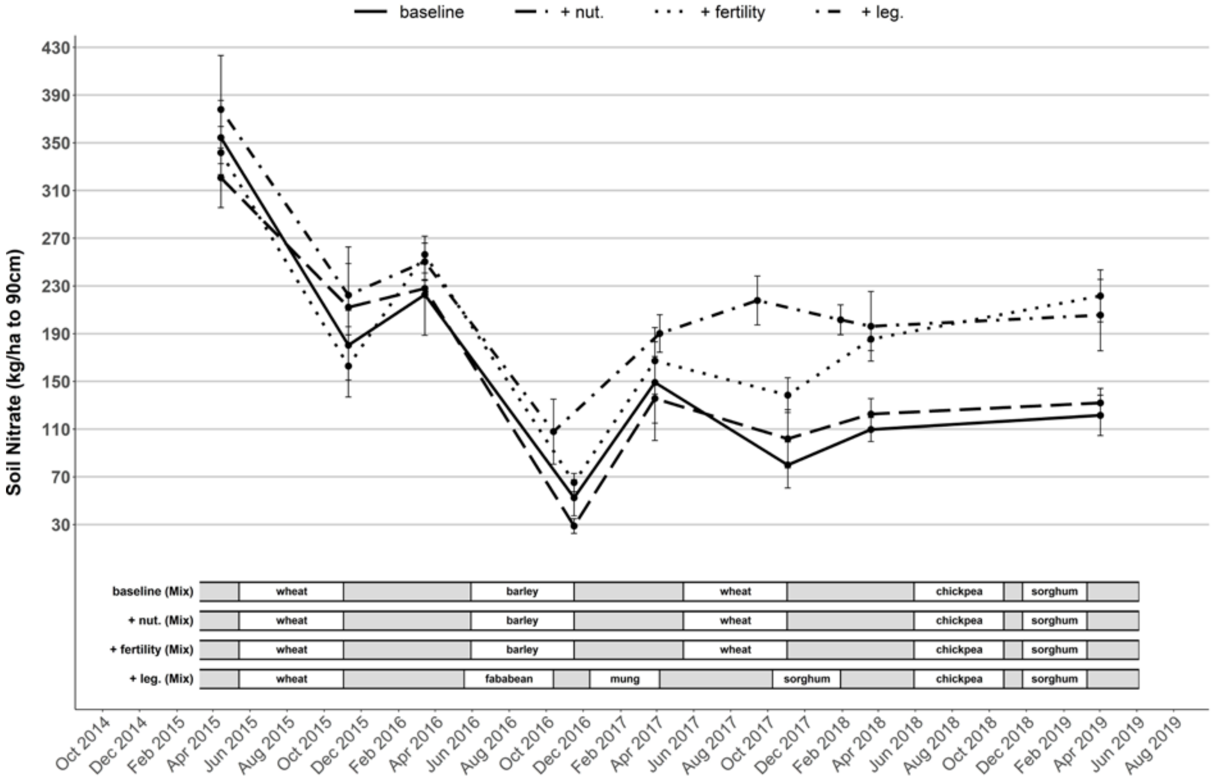

Figure 2. Dynamics of measured plant available soil nitrogen – Billa Billa

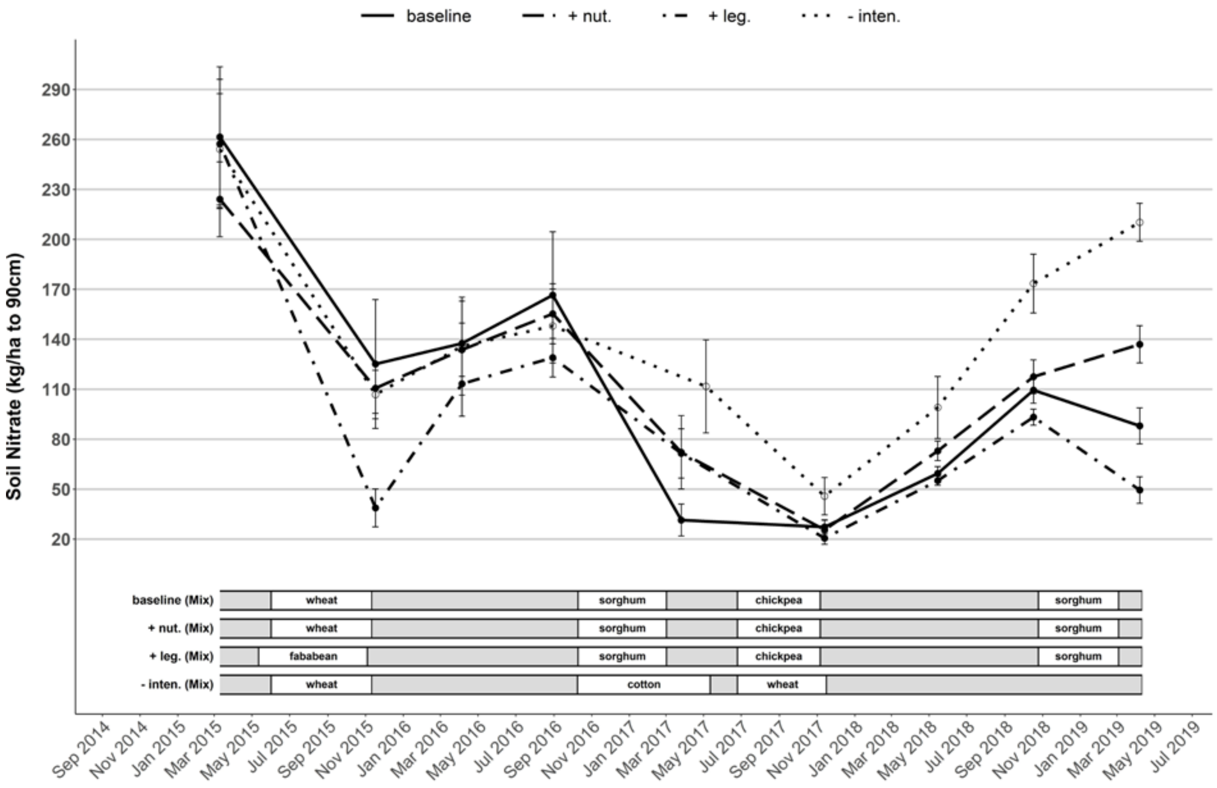

Figure 3. Dynamics of measured plant available soil nitrogen – Pampas mixed

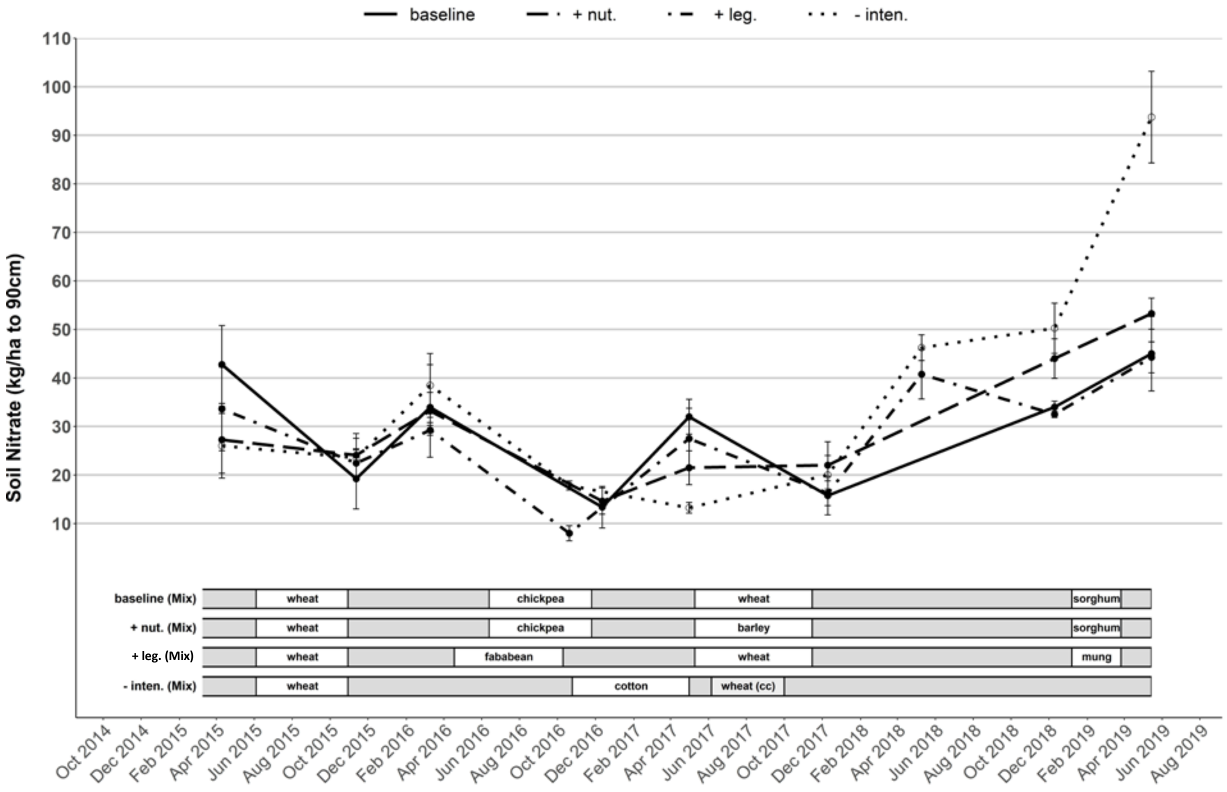

Figure 4. Dynamics of measured plant available soil nitrogen – Narrabri

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.

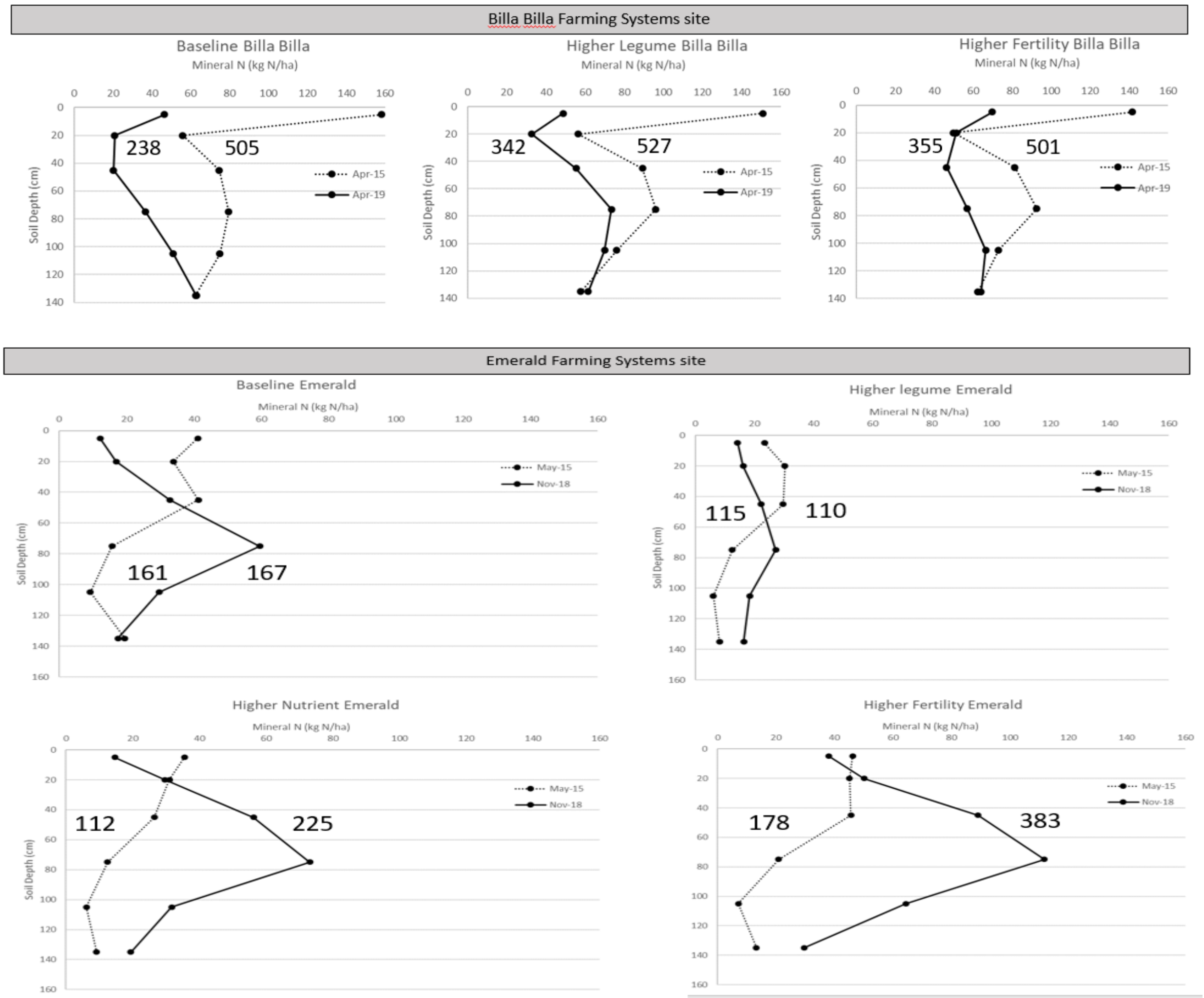

Figure 5. Distribution of mineral N placement within the soil profile from 2015 to 2019 at Billa Billa and Emerald

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.

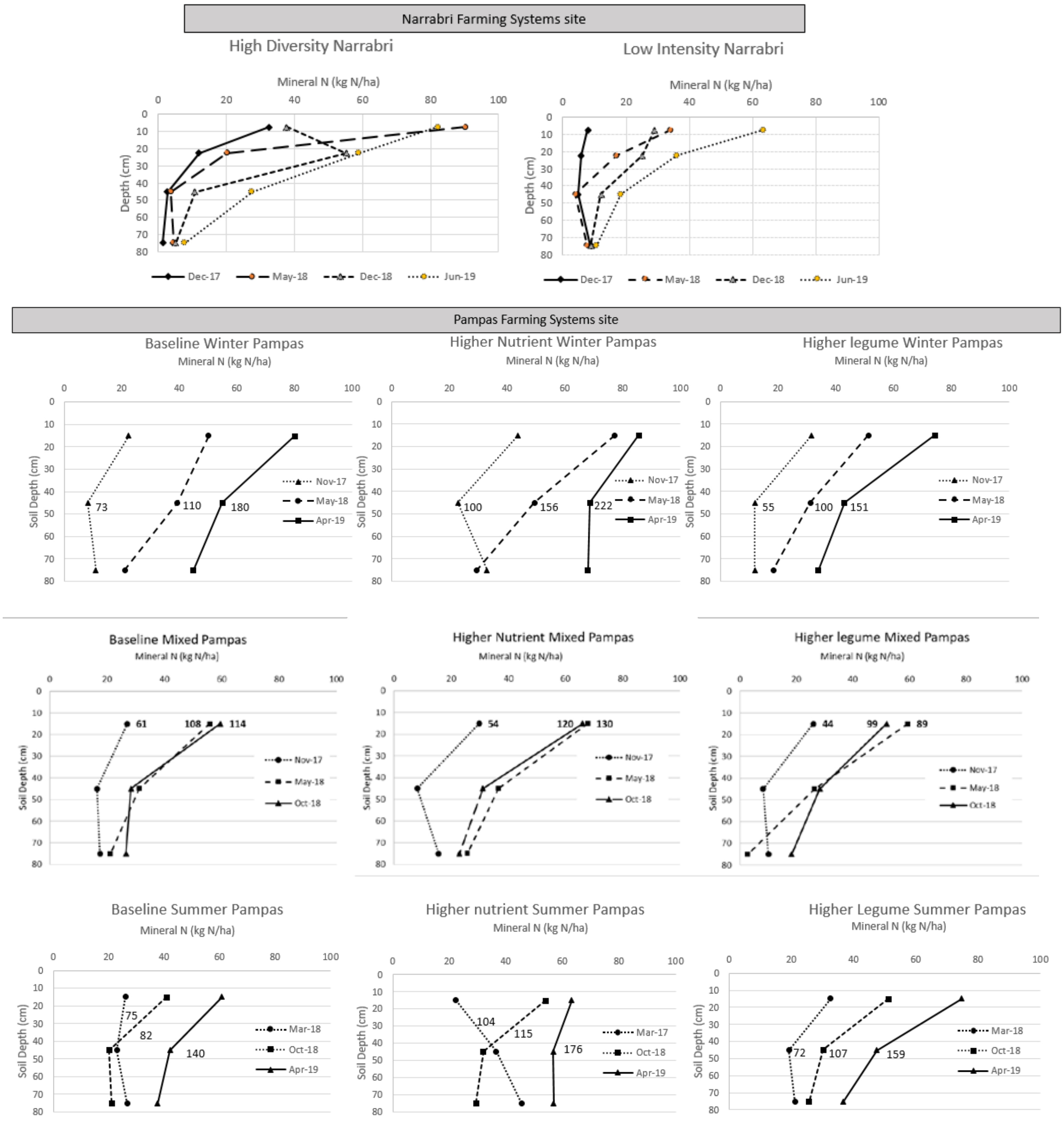

Figure 6. Distribution of mineral N placement within the soil profile over a long fallow period at Narrabri and Pampas

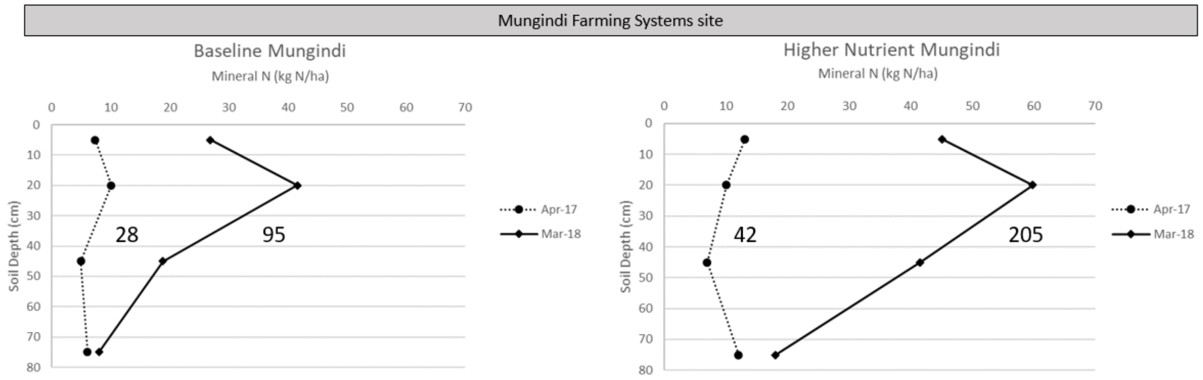

Figure 7. Distribution of mineral N placement within the soil profile over a long fallow period at Mungindi

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.

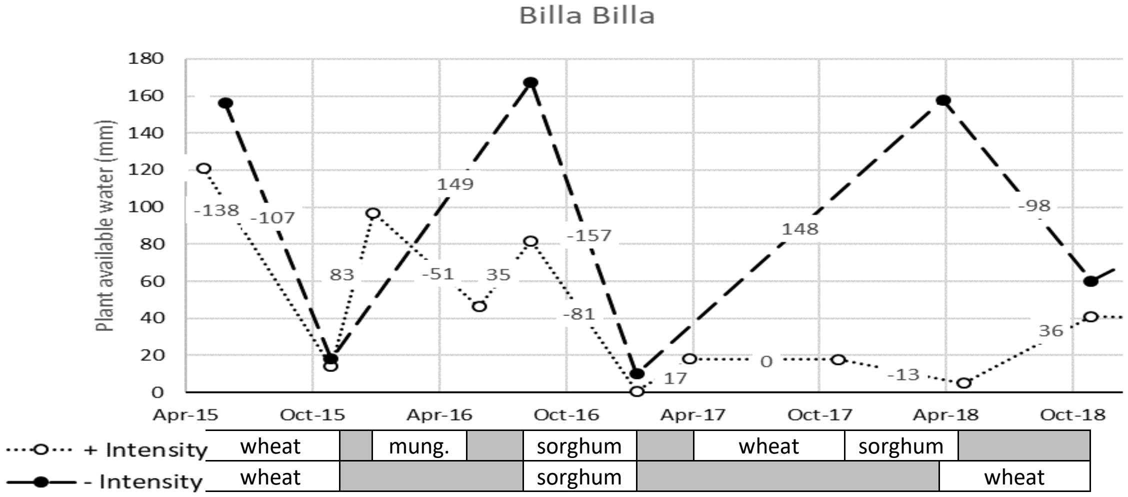

Figure 8. Plant available water (PAW) dynamics of two of the Billa Billa cropping systems. *Nb. Plots were often soil sampled up to 6 weeks prior to planting; crop duration indicated in the chart is from pre-plant soil sample to post-harvest soil sample (not plant to harvest). Numbers show the net change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

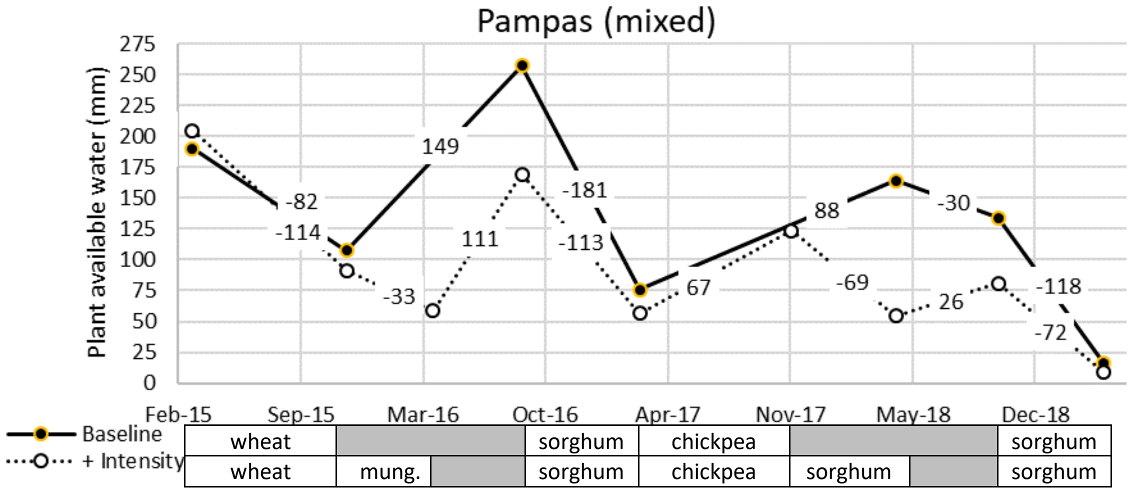

Figure 9. PAW dynamics of two of the Pampas mixed summer/winter cropping systems. *Nb. Plots were often soil sampled up to 6 weeks prior to planting; crop duration indicated in the chart is from pre-plant soil sample to post-harvest soil sample (not plant to harvest). Numbers show the net change between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

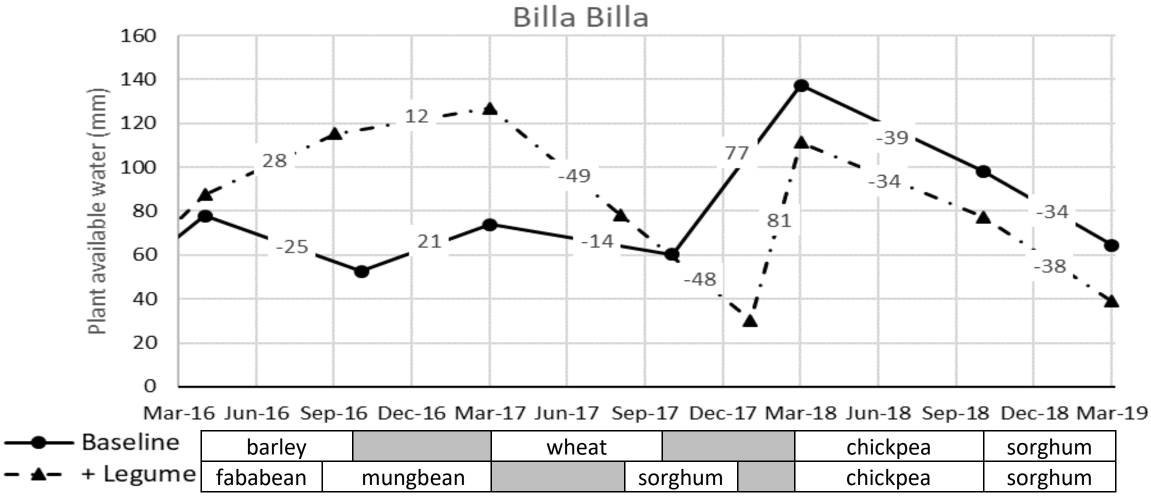

Figure 10. PAW dynamics of two of the Billa Billa cropping systems. *Nb. Plots were often soil sampled up to 6 weeks prior to planting; crop duration indicated in the chart is from pre-plant soil sample to post-harvest soil sample (not plant to harvest). Numbers show the net change between the two soil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

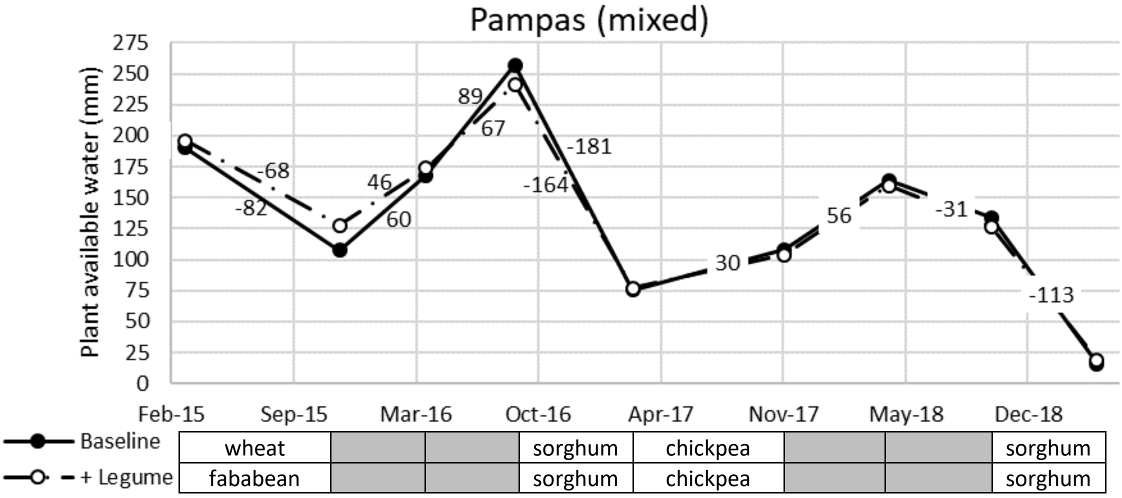

Figure 11. PAW dynamics of two of the Pampas mixed summer/winter cropping systems. *Nb. Plots were often soil sampled up to 6 weeks prior to planting; crop duration indicated in the chart is from pre-plant soil sample to post-harvest soil sample (not plant to harvest). Numbers show the net change between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

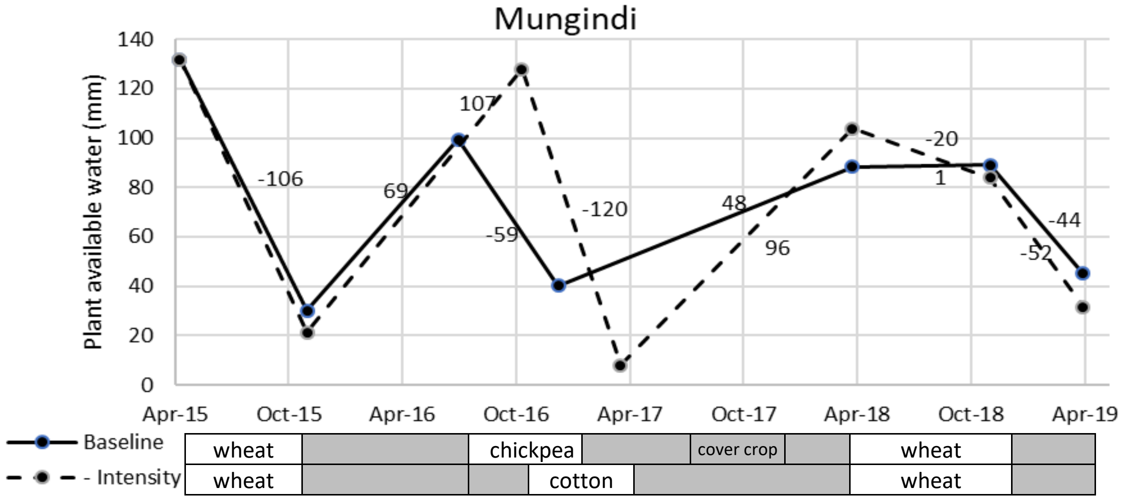

Figure 12. PAW dynamics of two of the Mungindi cropping systems. Numbers show the net change between the two soil water readings

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.

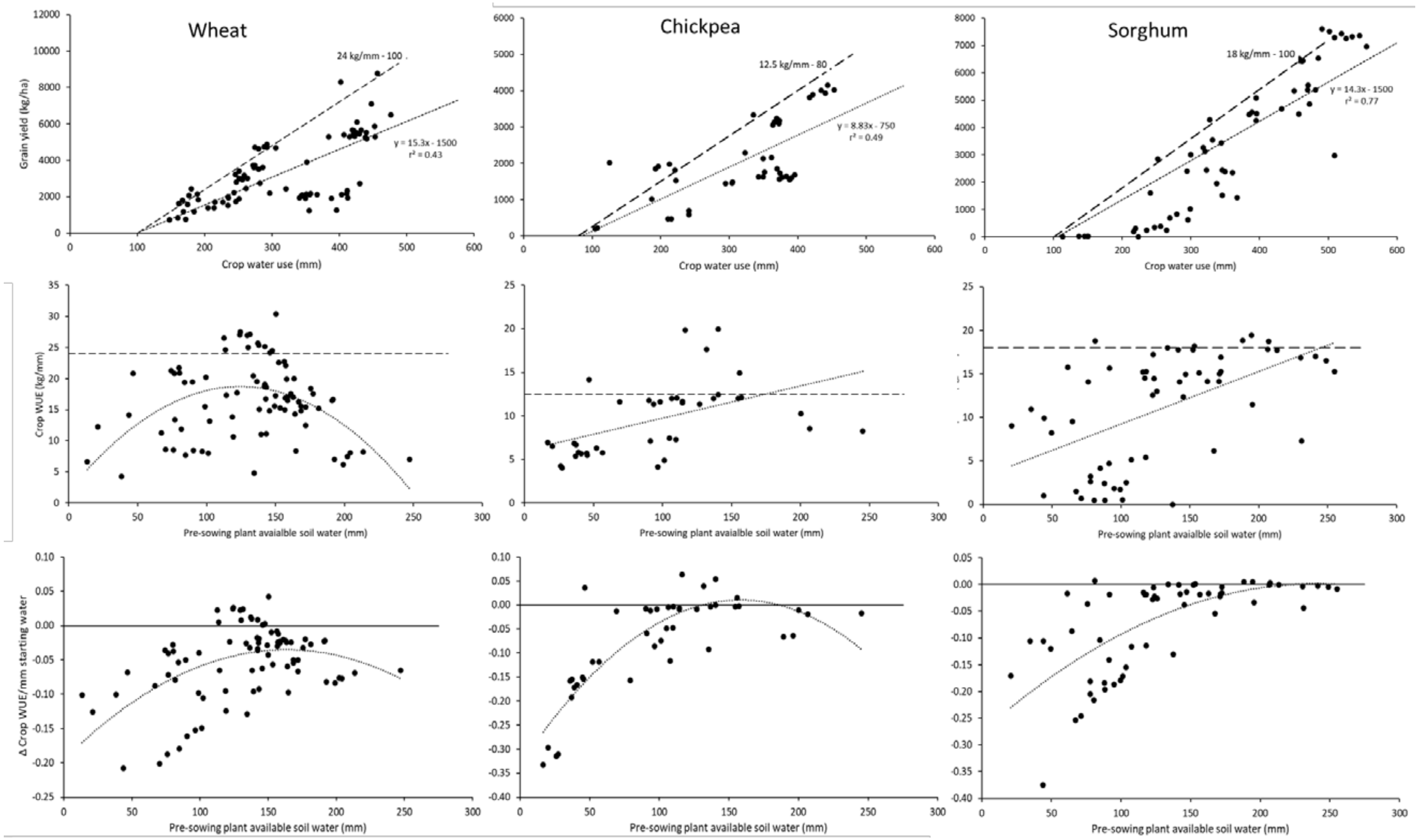

Figure 13. Relationships between water availability and crop yield and water use efficiency (WUE) in wheat, chickpea and grain sorghum collated from data collected across farming systems research sites. TOP –Crop water use (change in soil water plus rainfall) *vs.* grain yield, showing the maximum potential (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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GRDC code

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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.

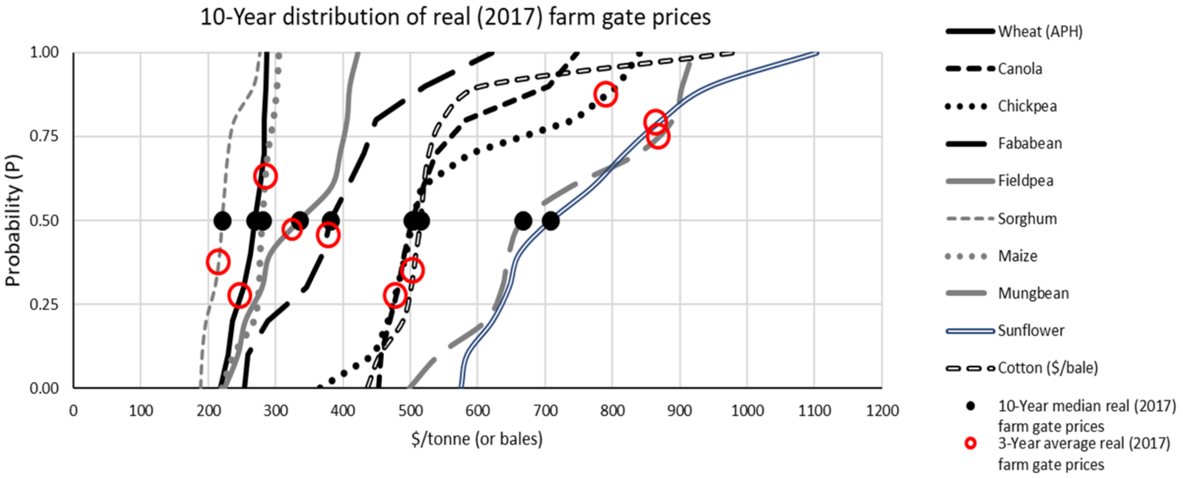

Figure 1. The probability distribution of annual average farm gate price of commodities (2008-2017) in the northern grain production region adjusted for inflation to 2017. The lowest annual price in this ten-year period is shown at P=0 on the y-axis and the highest price is at P=1. We used the 10-year 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.

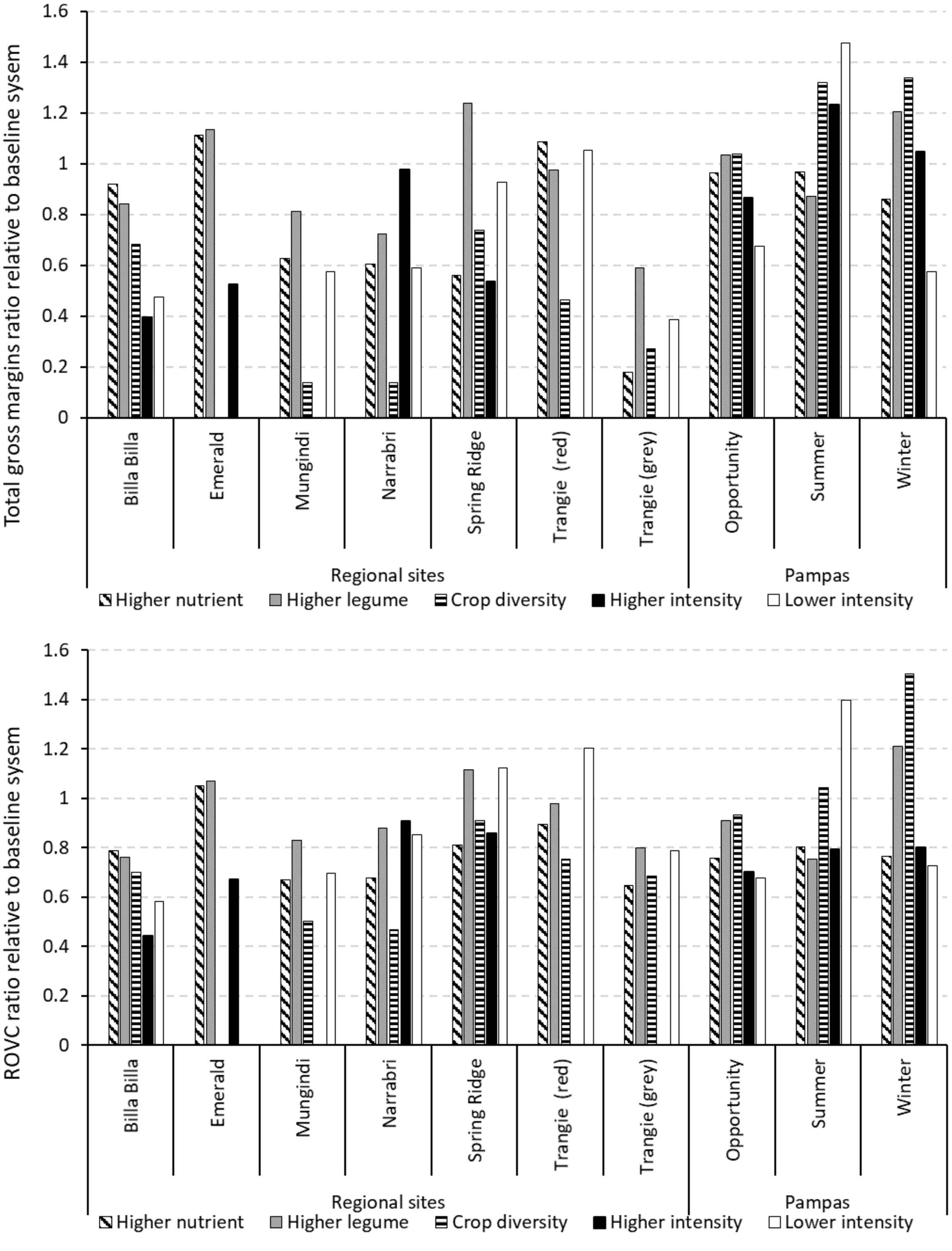

Figure 2. Relative system profitability of different farming systems as a ratio of the baseline system (i.e. 1 equals the baseline, higher is better and lower is worse) at 7 regional sites and under 3 different seasonal crops at the Core site (Pampas). Top shows the gross margin as a proportion of the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

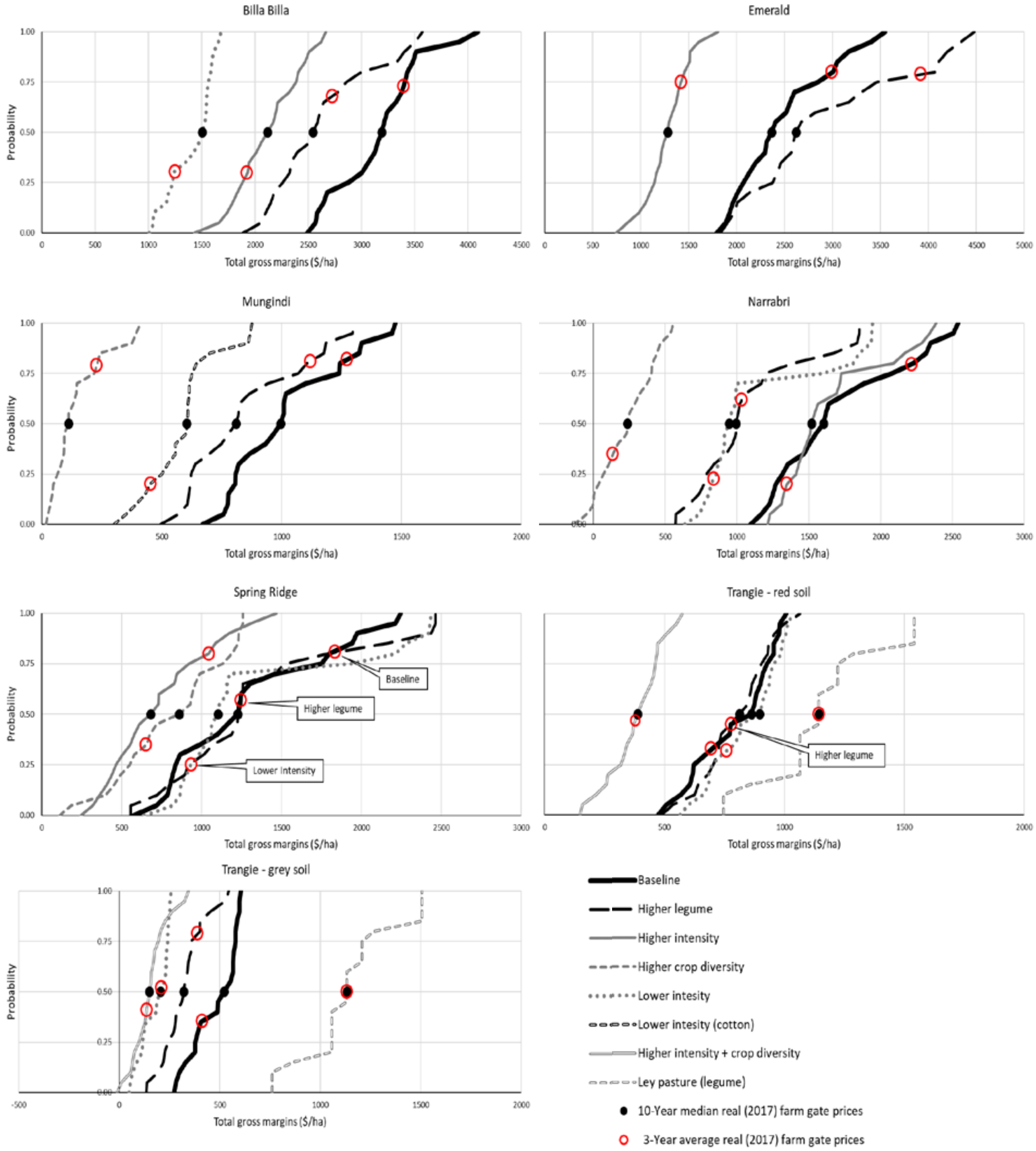

Figure 3. The distribution of total gross margins over 4.5 years calculated using the range of historical commodity prices for each farming system tested at regional locations across the NGR (Figure 1). The total gross margins with the lowest set of grain prices are shown where P=0 on and the highest 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.

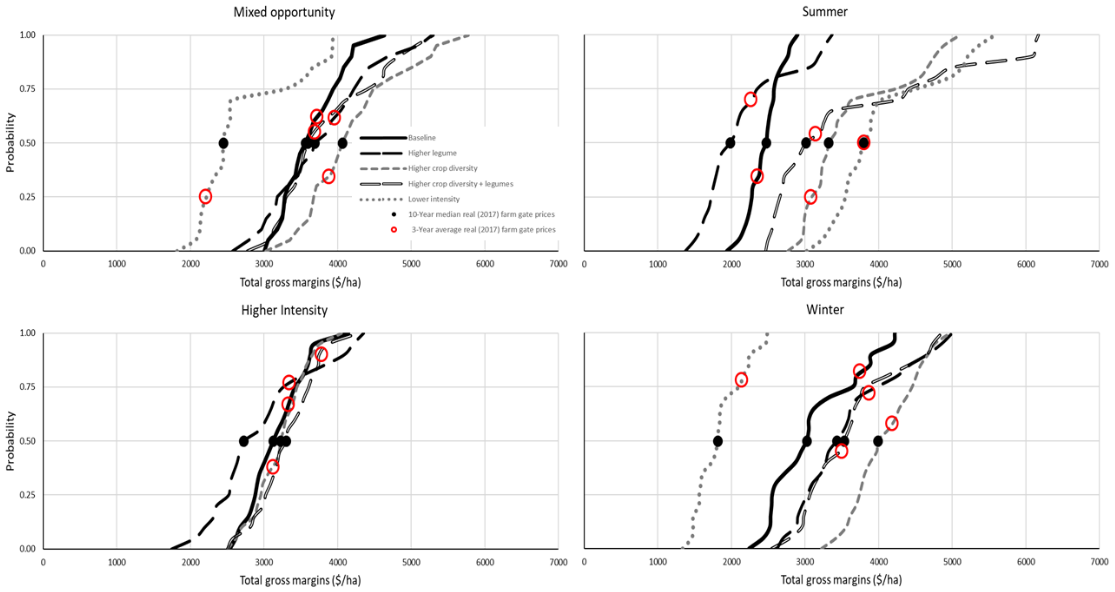

Figure 4. The distribution of total gross margins over 4.5 years calculated using the range of historical commodity prices for each farming system tested at the core experimental site, Pampas (Figure 1). The total gross margins with the lowest set of grain prices are shown where P=0 on and the highest 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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Integrating livestock into cropping systems using dual purpose crops- getting the best out of grazed crops. Crop type, agronomy varieties, nutrition and time of sowing

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Notes

Nutritional strategies to support productive farming systems

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Take home messages

- A critical success factor for cropping systems that rely heavily on stored soil water is co-location of plant nutrients with moist soil and active roots
- Our current fertiliser management practices need refinement, with low efficiency of fertiliser recovery often associated with nutrients and water being in different parts of the soil profile
- There needs to be greater consideration of placement and timing of fertiliser applications to improve fertiliser nutrient recovery
- Declining native fertility reserves means more complex fertilizer combinations will be needed to meet crop demands.

Introduction

This paper is based on a series of observations made in recent years from the projects listed above, as well as others made by Richard Daniel and the NGA team in their work on fertiliser N application strategies for winter crops. Collectively, the findings from this research, backed by the underlying regional trends in soil fertility and the drivers for successful rainfed cropping in our region, provide some useful insights into what are likely to be the critical success factors for future fertiliser management programs.

Do we have successful fertility management systems?

To maximise the chance of achieving effective use of available moisture, an effective fertiliser management strategy needs to consider all of the 4R's (right product, in the right place, at the right time and at the right rate – Johnson and Bruulsema 2014). While everyone pays lip service to these 4R's, our real thinking is often driven by considerations about only one – rate. We spend a lot of time agonising over rate, because rate is clearly an important part of the economics of growing the crop. Rate is also an important consideration in terms of soil fertility maintenance (i.e. replacing what we remove in grain). In many cases the rate we can afford is not always the rate we need to apply to optimise productivity, much less balance nutrient removal, but we still spend a lot of time thinking about it.

Because of that, we find that the thinking about the other 3R's tends to be much more superficial. Occasionally we might have a try at something a bit different, but in many cases we tend to keep doing what we have always done, and put the same products in the same place at the same time each year. Meanwhile, our background soil fertility reserves have fallen and our crops are becoming increasingly reliant on off-farm sources of fertility (fertilisers, manures etc.) to sustain productivity. It is this increasing reliance on fertilisers, especially N, P and (increasingly) K, that is allowing us to really see the inefficiency in current use practices. The impact of these inefficiencies in terms of lost productivity can often dwarf any of the considerations of rate, and are highlighting challenges for productivity and profitability in the long term.

We will now cover some examples of inefficiencies that are apparent in what has been considered as best practice for both N and P, and how the emergence of K infertility is adding further complexity to fertiliser best practice.

Management of fertiliser N

In the case of N in winter cereals, the recent comprehensive analysis of a series of N experiments from 2014-2017 by Daniel et al. (2018) highlighted the poor winter crop recovery of fertiliser N applied in the traditional application window (the months leading up to sowing, or at sowing itself). Fertiliser N recovered in grain averaged only 15% for applications of 50 kg N/ha and 9% for 100 kg N/ha. On average, 65% of the applied N was still in the soil as mineral N at the end of the crop season, while an only 15% was in the crop (grain and stubble). The fate of the other 20% of applied N could not be determined. Some of the soil and stubble N will carry over until the next season, but it means that you need last year's residual fertiliser to get you through this year. If you had a big year last year (little residual N) or lost a lot of the N carryover during a wet season, the current crop will suffer.

The poor winter crop recovery of applied N in the year of application mirrored that reported for summer sorghum in the NANORP research program reported by Bell, Schwenke and Lester (2016), with the use of ^{15}N tracers enabling a more precise quantification of the fate of N applied prior to planting. Data from the Queensland sites in commercial fields are shown in Figure 1 for the 40 and 80 kg N rates across three growing seasons. Fertiliser N in grain averaged 27% and 23% of the applied N for the 40 and 80N rates, respectively, while total crop uptake averaged only 37% and 32% for the same N rates. What is noticeable in this figure is the variable N losses (presumably via denitrification) and the residual N in the soil, which may or may not be available for a subsequent crop in the rotation, depending on the fallow conditions. Schwenke and Haig (2019) reported good carryover of fertiliser applied for the 2013/14 sorghum crop for recovery by the 2014/15 season under favourable fallow conditions, while extensive loss of residual soil N after summer crops was experienced over large areas during the wet 2016 winter fallow.

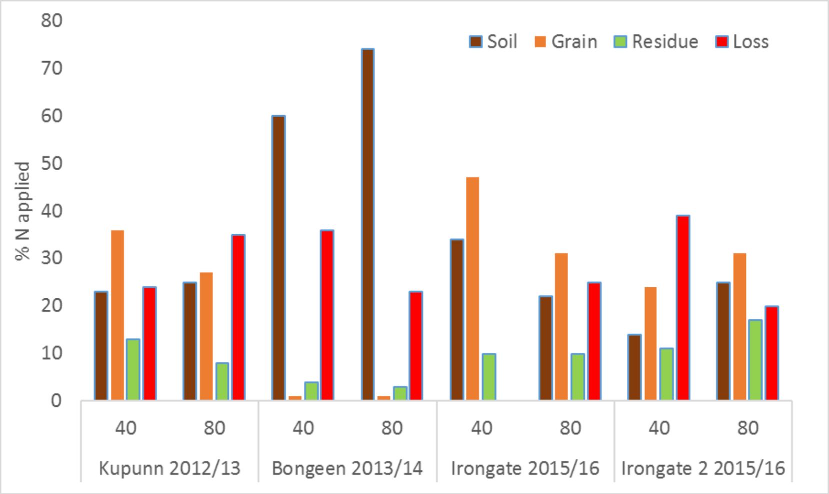


Figure 1. Partitioning of fertiliser N between soil, plant and environmental loss pools for summer sorghum crops grown on the Darling Downs in UQ00066 from 2012 – 2016

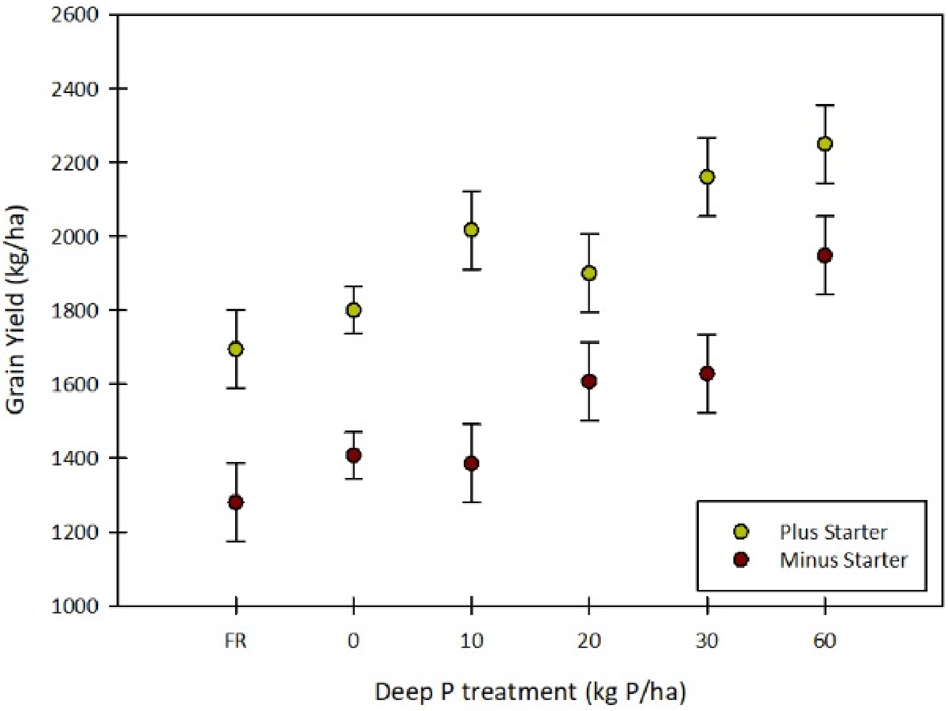
All studies have shown there can be significant amounts of residual N in the soil at the end of the growing season. Large amounts of that N are often found in quite shallow parts of the soil profile (i.e. the 0-10cm and possibly 10-20cm layers) and still strongly centred on the fertiliser bands, despite what were often significant falls of rain in-crop (i.e. 200-300mm). Even after a subsequent fallow, the Daniel et al. (2018) paper reported that 50-60% of the mineral N residual from fertiliser applied in the previous season was still in the top 45cm, with as much as half of this still in the 0-15cm layer. This largely surface-stratified residual N would have contributed to the quite muted (although still significant) grain yield response to the residual N in those studies.

Interestingly, findings from both the summer sorghum and winter cereal research suggest that crops recover mineral N that is distributed through the soil profile with much greater efficiency than fertiliser applied at or near sowing. In both seasons, 70-80% of the mineral N in the soil profile was recovered in the crop biomass, compared to recoveries of applied fertiliser that were commonly less than half that. The distribution of that N relative to soil water is likely to have played a major role in this greater recovery efficiency.

Management of fertiliser P

The substantial responses to deep P bands across the northern region where subsoil P is low have been detailed in a number of recent publications (Lester et al. 2019b, Sands et al. 2018), with these responses typically additive to any responses to starter P fertiliser (the traditional P fertiliser application method – e.g. Figure 2a, b). There has unfortunately been no direct measurement of P unequivocally taken from either deep or starter P bands due to the lack of suitable tracer technology, especially when we consider residual benefits over 4-5 years. However, simple differences in biomass P uptake in a single season suggest that the quantum of P accumulated from deep bands (3-5 kg P/ha) is substantially greater than that from starter P alone (1-1.5 kg P/ha) in all bar exceptionally dry seasons.

a)



b)

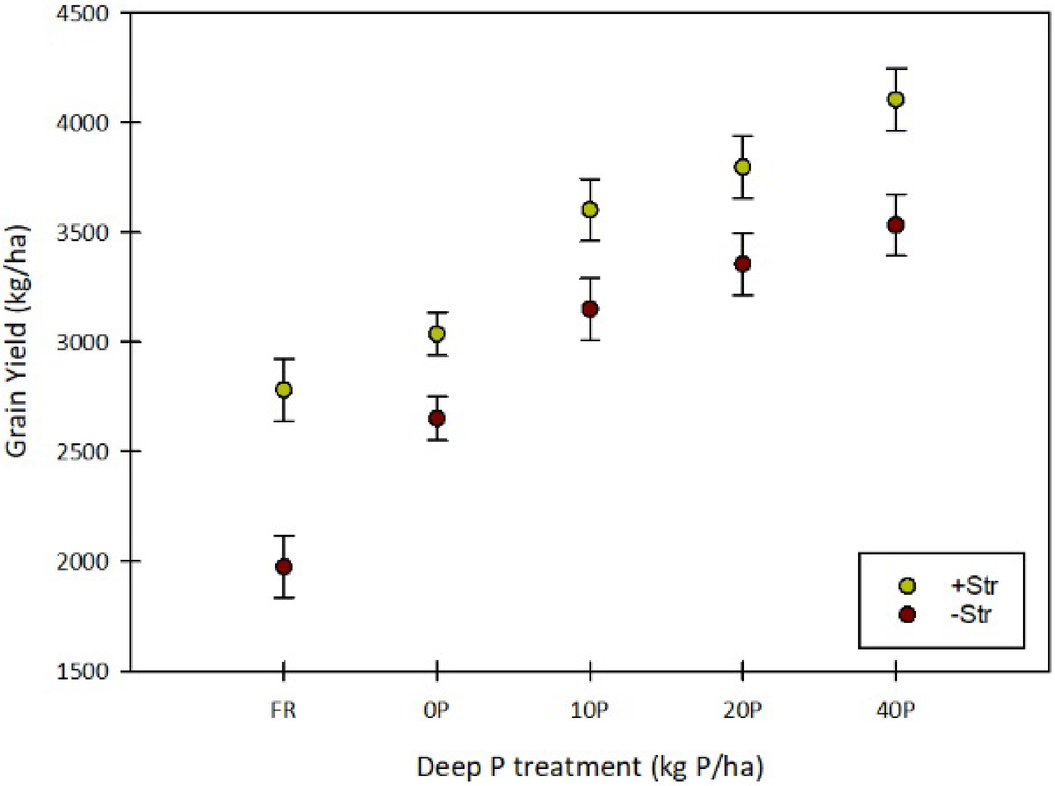


Figure 2. Response to different rates of deep P with and without applications of starter P fertiliser in (a) a wheat crop at Condamine in 2018 wheat, and (b) a sorghum crop at Dysart in 2018/19 grain yield for deep-placed P treatments (kg P/ha) with or without starter application. The vertical bars represent the standard error for each mean. (Lester et al. 2019a)

Perhaps one of the most significant findings from the deep P research has been the relative consistency of P acquisition from deep bands, despite significant variability in seasonal conditions. Research results from sites in Central Qld (CQ) often provide the best examples of this, due to the extremely low subsoil P reserves in some of those situations – if the crop cannot access the deep P bands, there is not much to find anywhere else in the subsoil! Interestingly, this type of profile P distribution is consistent with the lack of grain yield responses to starter P that were recorded over a number of years of trials in CQ and that contributed to reluctance to use starter P in some situations. Early growth responses that were consistent with the crop obtaining an extra 1-1.5 kg P/ha from the starter application were observed, but a lack of available profile P to grow biomass and fill grains limited any resulting yield responses.

The inability to acquire P from a depleted subsoil places greater importance on access to P in the topsoil, which means that seasonal rainfall distribution can have a huge impact on crop P status. This is illustrated for a site near Clermont in Figure 3 (a, b), in which the growing season conditions and crop P acquisition by successive crops of sorghum and chickpea are compared. From a yield perspective, deep P increased crop yield by 1100 kg and 960 kg for the sorghum and chickpea crops, relative to the untreated Farmer Reference treatment, and by 720 kg and 970 kg/ha for the same crops relative to the 0P treatment that received ripping and other background nutrients. The similar size of yield responses in the two crops represented quite different relative yield increases (40-60% in the sorghum, versus about 300% in the chickpeas), and obviously had hugely different impacts economically, given the price differential between sorghum and chickpea grain. However, from a nutrient use efficiency perspective it is interesting to note that the apparent P acquisition from the deep P bands was similar (3.3 kg P/ha in the sorghum and 2.7 kg P/ha in the chickpeas – Figure 3b)) despite the vastly different in-season rainfall (Figure 3a).

What is dramatically different, and what is driving the much larger relative yield response in the chickpea crop, was the inability to access P without deep P bands in that growing season. Crop P contents in the Farmer Reference and 0P treatments averaged 2.9 kg P/ha in the sorghum crop but only 0.6 kg P/ha in the chickpeas. This difference was driven by the combination of deep sowing and extremely dry topsoils encountered in the 2018 winter season. The chickpea crop was planted below the 0-10cm layer, and there was never enough in-season rainfall to encourage later root growth and P recovery from that layer. Despite available moisture in the subsoil, there was not much P available to support growth and yield. In contrast, the sorghum crop was planted into the relatively P-rich top 10cm layer, which was then rewet regularly over a significant proportion of the vegetative phase. This allowed better P acquisition from the background soil, but the deep P bands were still able to supplement this and provide an additional yield benefit.

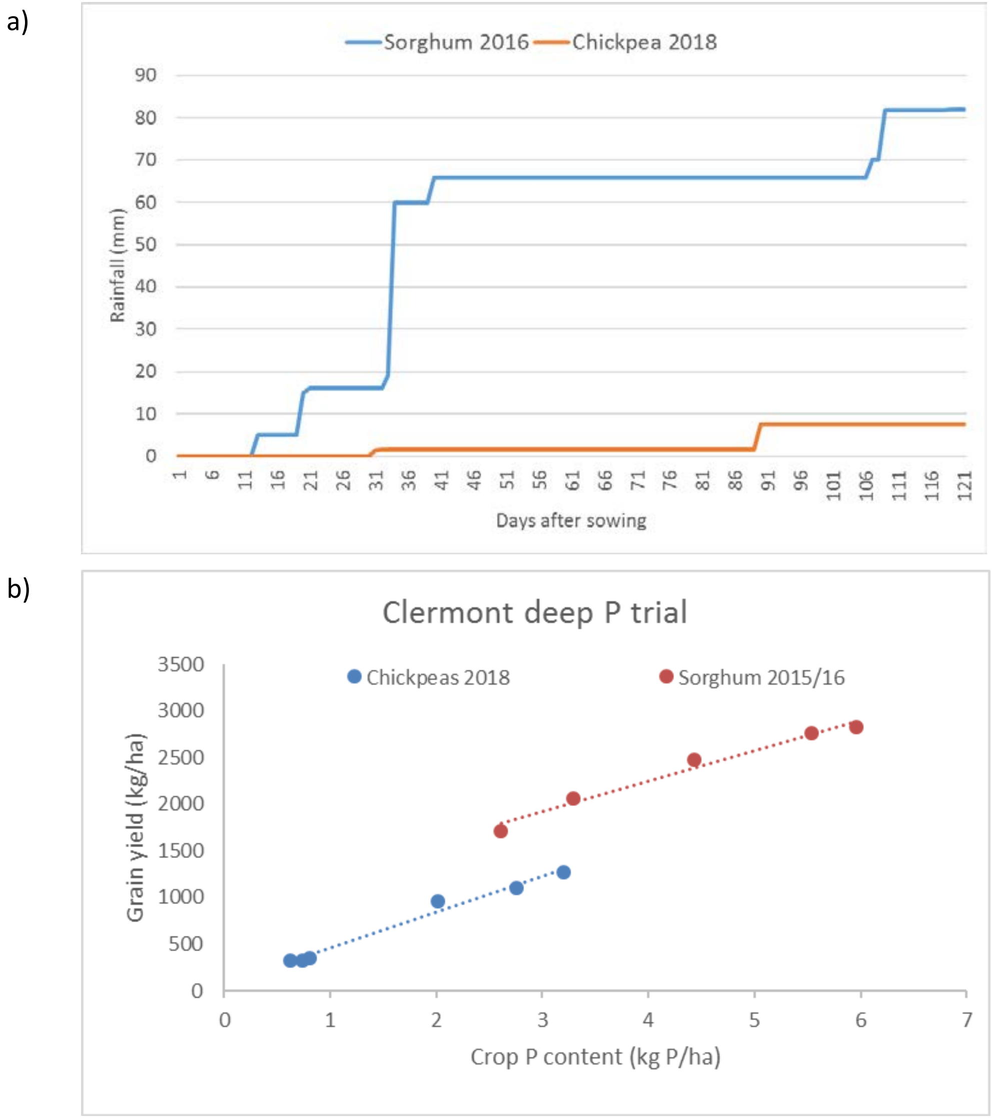


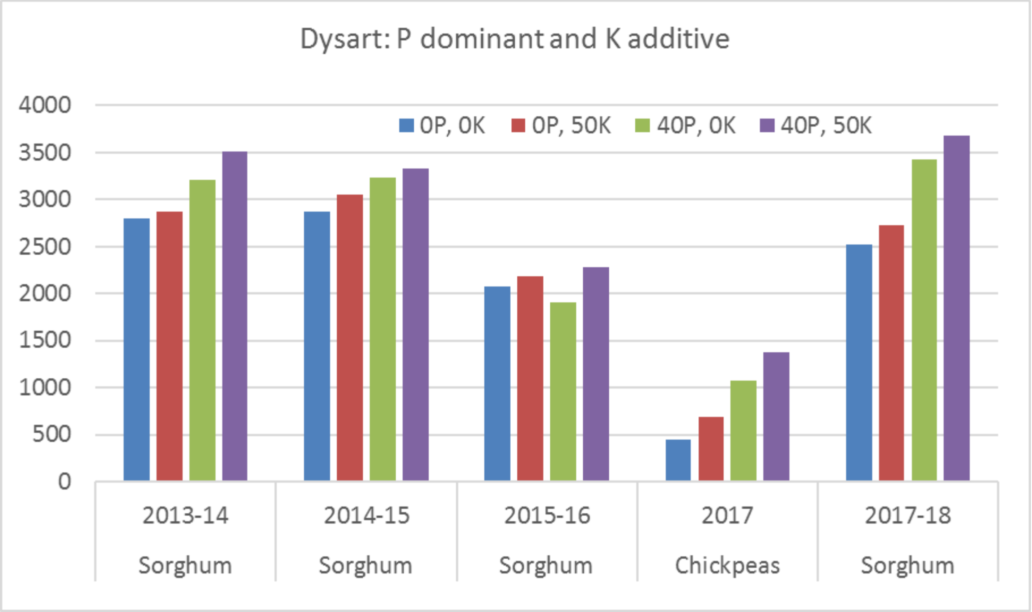
Figure 3. (a) Cumulative in-crop rainfall and (b) the relationship between crop P content and grain yield for consecutive crops of sorghum (2015/16) and chickpea (2018) grown at a site near Clermont, in Central Queensland (Sands et al., 2019)

Choice of product to address multiple nutrient limitations

As native fertility has been eroded by negative nutrient budgets and/or inappropriate placement, there are an increasing number of instances of complex nutrient limitations that require compound fertilisers to address multiple constraints, with the relative severity of each constraint changing from season to season. Perhaps the best example has been the emergence of widespread examples of K deficiency in recent (drier) seasons, but which can 'disappear' in more favourable ones. This is an example of the impact of increasingly depleted and more stratified K reserves, and is an issue that adds complexity to fertility management programs. Soil testing benchmarks for subsoil nutrients are improving as a result of current programs, but at best they are only likely to ring alarm bells for the different constraints, rather than predict the relative importance of each in future (uncertain) seasonal conditions. Examples provided in Figure 4, again from sites in CQ, show fields where subsoil P and K would both be considered limiting to productivity, but the responses to deep placed P and K have varied with crop and seasonal conditions. Assuming enough N is applied, the site at Dysart shows a dominant P constraint which is evident in most seasons, and a smaller K limitation that is only visible once the P constraint has been overcome. The Gindie site, on the other hand, has limitations of both P and K, but the relative importance of each constraint seems to depend on the crop choice and/or seasonal conditions. In both cases, the appropriate agronomic response would be to apply both nutrients, but the relative economic returns of adding K to the fertiliser program (as opposed to higher/more frequent P additions) would be different.

The emergence of multiple constraints such as those shown in Figure 4 require a greater understanding of the implications of co-location of different products, especially in concentrated bands applied at high(er) rates, less frequently. There is evidence that effective utilisation of banded K, at least in Vertosols, is dependent on co-location with a nutrient like P to encourage root proliferation around the K source (Figure 5 – Bell et al., 2017). However, there is also evidence that there can be negative interactions between P and K applied together in concentrated bands that can reduce the availability of both nutrients. There is an existing investment (UQ00086) exploring the reactions that occur in bands containing N, P and K, and the implications of changing the products and the in-band concentrations on nutrient availability.

a)



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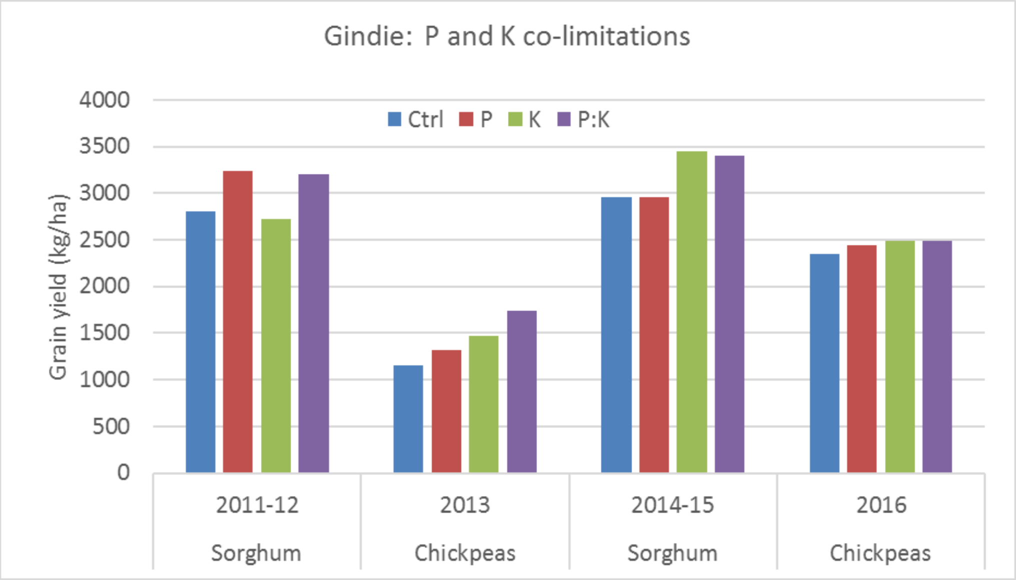

Figure 4. Examples of combinations of P and K limitations to crop performance at (a) Dysart and (b) Gindie, and the response to deep banded applications of those nutrients alone, or in combination

What are the key farming systems characteristics complicating nutrient management?

The changing nutrient demands in dryland grains systems, especially on Vertosols, are driven by the combination of nutrient removal that has not been balanced by nutrient addition (especially in subsoil layers), and the reliance of our cropping systems on stored soil water for long (and in some cases all) of the growing season. Crops need access to adequate supplies of water and nutrients to perform, and while crop roots can acquire water from a soil layer with little to no nutrient, they certainly can't acquire nutrients from soil layers with little or no available moisture. The co-location of water, nutrients and active crop roots enable successful crop production. Historically our cropping systems have been successful because (i) soils originally had moderate or higher reserves of organic and inorganic nutrients; (ii) there were sufficient reserves of those nutrients at depth so the crop could still perform when the topsoil was dry; and (iii) our modern farming systems are now much better at capturing water in the soil profile for later crop use.

Our soils are becoming increasingly characterised by low organic matter, with reserves of P and K that are concentrated in shallow topsoil layers and depleted at depth. Our typical fertiliser management program applies all nutrients into those topsoil layers, with the immobile ones like P and K staying there, and the mobile nutrients like N applied late in the fallow or at planting, when there is no wetting front to move the N deeper into the subsoil layers. Without that wetting front, even mobile nutrients like N are not able to move far enough into the soil profile to match the distribution of water – at least for the targeted crop season. We also grow a very low frequency of legumes in our crop rotation, which increases overall fertiliser demand and produces residues that are slow to decompose and release nutrients during the fallow and for the following crop. This means that nutrients like N are mineralised later in the fallow, again with less chance to move deeper into the soil profile for co-location with stored water.

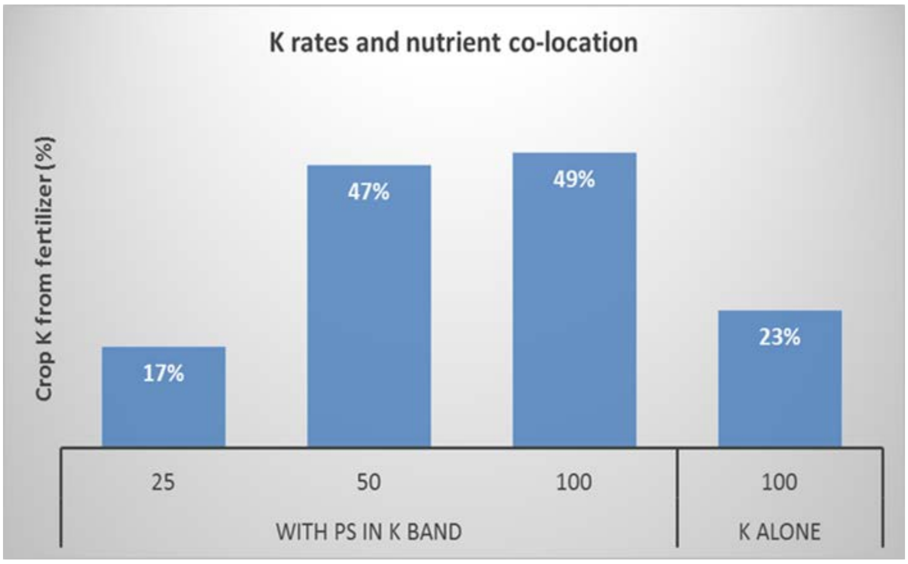

Figure 5. The impact of rate of applied K and co-location of K with other nutrients in a band (in this case P and S) on the proportion of crop K that was derived from applied fertiliser

The net result is an increasing frequency of dislocated reserves of stored soil water and nutrients, with in-crop rainfall at critical stages being a major determinant of whether the crop will be able to acquire the nutrients to achieve the water-limited yield potential. Unless our management systems change to address these issues, there will inevitably be a decline in overall water use efficiency across the cropping system, with an increasing frequency of poor or unprofitable crops. The changes that we think are needed require a stronger focus be placed on the 'forgotten' 3R's – right product (product choice/combination), in the right place, at the right time.

In the concluding section of this paper, we provide a brief outline of what we feel are going to be key strategies that need to be considered in future nutrient management programs. We note that a number of these have not yet been extensively validated, or are simply hypotheses that are worthy of testing. However, they do provide what we think are opportunities to address some of the main nutrient supply issues outlined in the preceding sections of this paper.

Future nutrient management opportunities

In general

- Focus more on feeding the soil to support the farming system, in addition to targeting the next crop in the rotation sequence. This will involve applying nutrients at a time and in a part of the soil profile that maximises the chance of having nutrients co-located with water when future crops need it. Making those decisions once the profile water has largely accumulated and the planting decision is more certain is resulting in frequent spatial dislocation between nutrient and water supply
- Where possible, legume crops should be grown with greater frequency, as they reduce the fertiliser N demand. This will allow diversion of money from the fertiliser budget spent on N into other nutrients that can be exploited across the rotation
- Be adaptive in your fertiliser management program. Respond to the opportunities that are offered to put the right nutrient in the right place at the right time, and chose the right combination of products to match the soil nutrient status. This will involve a good understanding of the variation in profile nutrient status from field to field, and also understanding how seasonal conditions may impact on those application decisions.

For specific nutrients

Nitrogen (N)

- Understanding the soil water holding and drainage characteristics is critical, as strategies appropriate for heavy clays will not be suitable for lighter textured soils. For example, in clay soils you should be prepared consider changing the timing of at least some of the fertiliser N input, so it is applied into dry soils at the beginning of a fallow. The Daniel et al. (2018) paper showed nice examples of how early fallow N applications can increase the proportion of fertiliser N that is accumulated in deeper profile layers, potentially ensuring N availability with deep water to enable continued growth when the crop is experiencing dry periods. The greater efficiency of recovery of distributed 'soil' N compared to freshly applied fertiliser may allow possible rate reductions that could help to offset any interest paid on early fertiliser investment
- Be aware when conditions have changed from the 'normal' upon which your current fertiliser strategies have been based. For example, what would differences in (especially shallow) profile moisture status at the beginning of a fallow mean for the denitrification risk to early N applications? How should you respond to an unusually large crop that has depleted the soil N profile and left stubble that is low in N? How would you respond to an unseasonal rainfall event after N applications had been made?
- Legume residues should better synchronise the release of N with the recharge of profile moisture during a fallow. This should result in soil N that is more readily accessible during a following crop, as well as a lower fertiliser N requirement.

Phosphorus (P) and Potassium (K)

- Don't ignore starter fertilisers, but also be aware that they are not an effective solution to meeting crop P demand in most seasons, and adding K to starter blends can impact the 'salt' risk to crop establishment
- While there is no requirement for starter K to meet early growth demands, starter P has an important role to play in early season growth and establishing yield potential, even though the amount of P acquired from the starter P band is quite small. There may be opportunities to reduce the rates of P applied at planting if uniform distribution along the seeding trench can be maintained, where fluid forms of P may possibly having a role. The 'saved' P should be diverted into increased rates or frequencies of deep P application
- Starter P is especially important in very dry seasonal conditions, and can have an unusually large impact on crop P uptake due to restricted access to the rest of the P-rich topsoil. Under these conditions, starter P can also have a large impact on secondary root growth and improved soil P access
- Deep P and K work – use them. Question marks still exist about the length of the residual effect, and some of the risks from co-locating products in a band. Minimise the risk by applying products in more closely spaced bands (i.e. at lower in-band concentrations) more often (i.e. lower application rates)
- Remember that the main subsoil constraint has generally been P, so get the P rate right and complement that with additional K as funds allow
- Don't let subsoil P and K fall too far! Whilst we have got some great responses to deep P (and K) bands, and they are certainly economic, we have not seen evidence that a deep banded application (of P at least) is sufficient to completely overcome a severe deficiency. The band is a very small proportion of the soil volume, and when roots proliferate around a band, they dry it out. Unless the band area re-wets during the season, allowing roots a second opportunity to access the banded nutrient, the amount of nutrient recovered will be limited. In short, bands provide a useful but not luxury supply. Nutrient concentrations in foliage and grains still show signs of crops that are still P deficient in many situations, and it is obvious that the greater the

volume of subsoil that can be fertilised (more bands, more often) the greater the chance we have of meeting crop demand.

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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

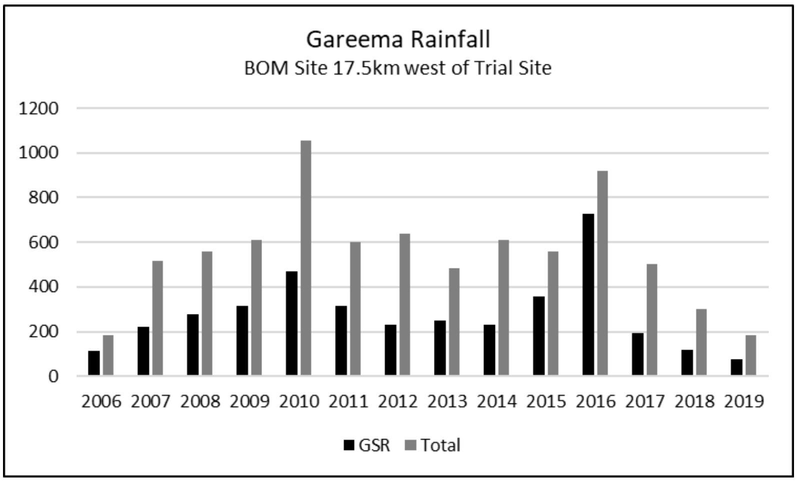

Figure 1. Gareema rainfall 2006 – 2019

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)

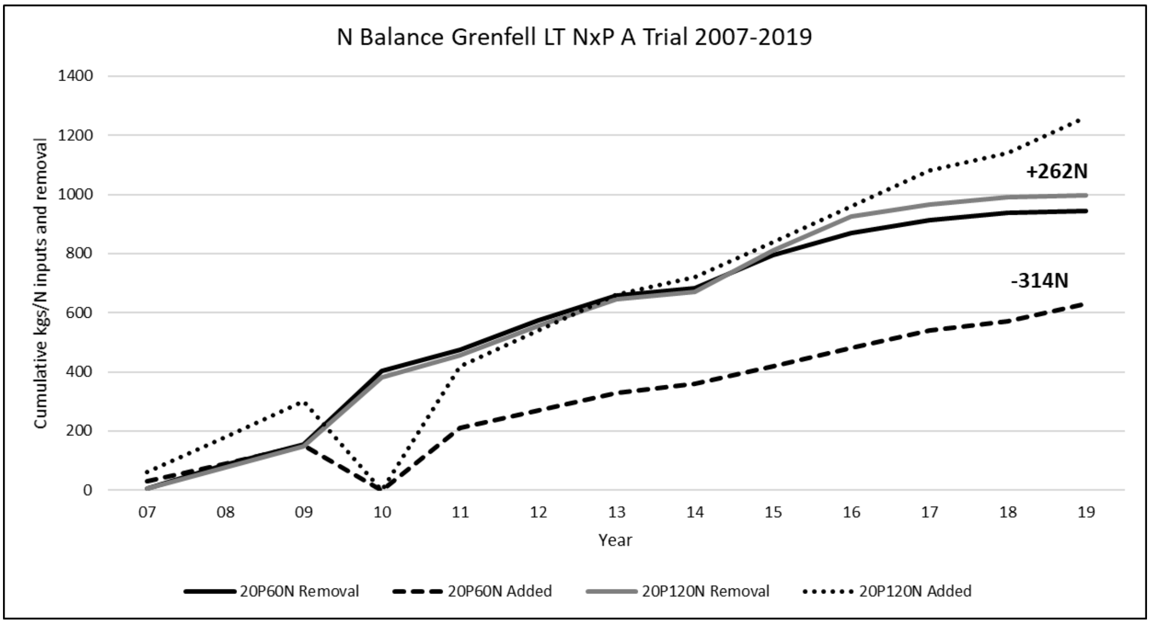

Figure 2. N balance at Grenfell trial 2007 – 2019

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.

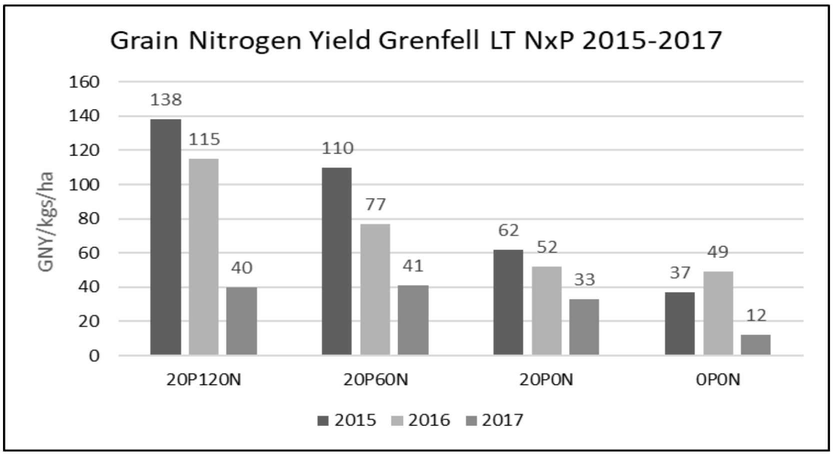

Figure 3. Grain nitrogen yield at Grenfell 2015-2017

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).

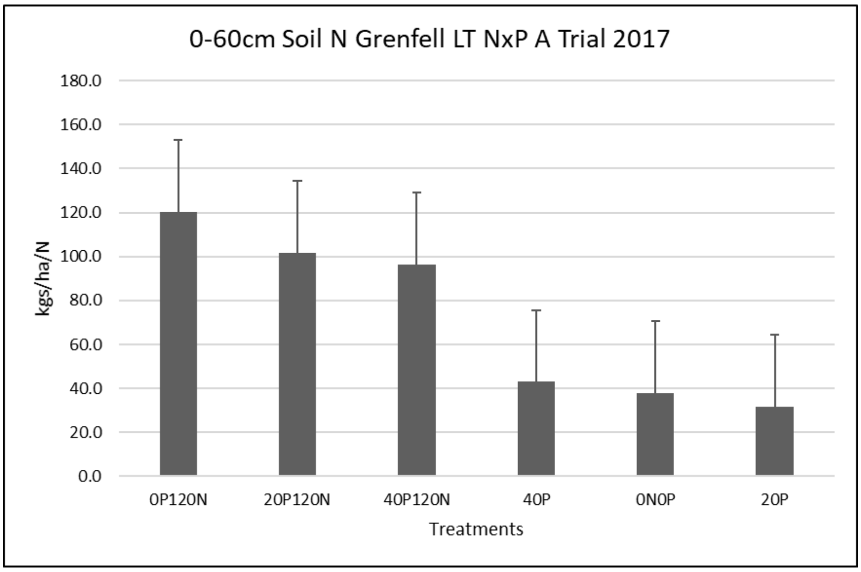

Figure 4. 0-60cm soil N at Grenfell long term NxP A trial 2017

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.

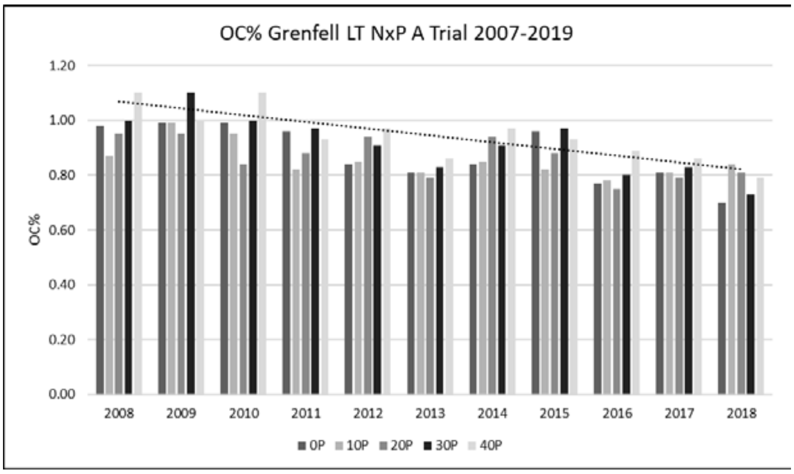

Figure 5. Organic carbon % at Grenfell long term NxP A trial 2007-2019

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.

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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.

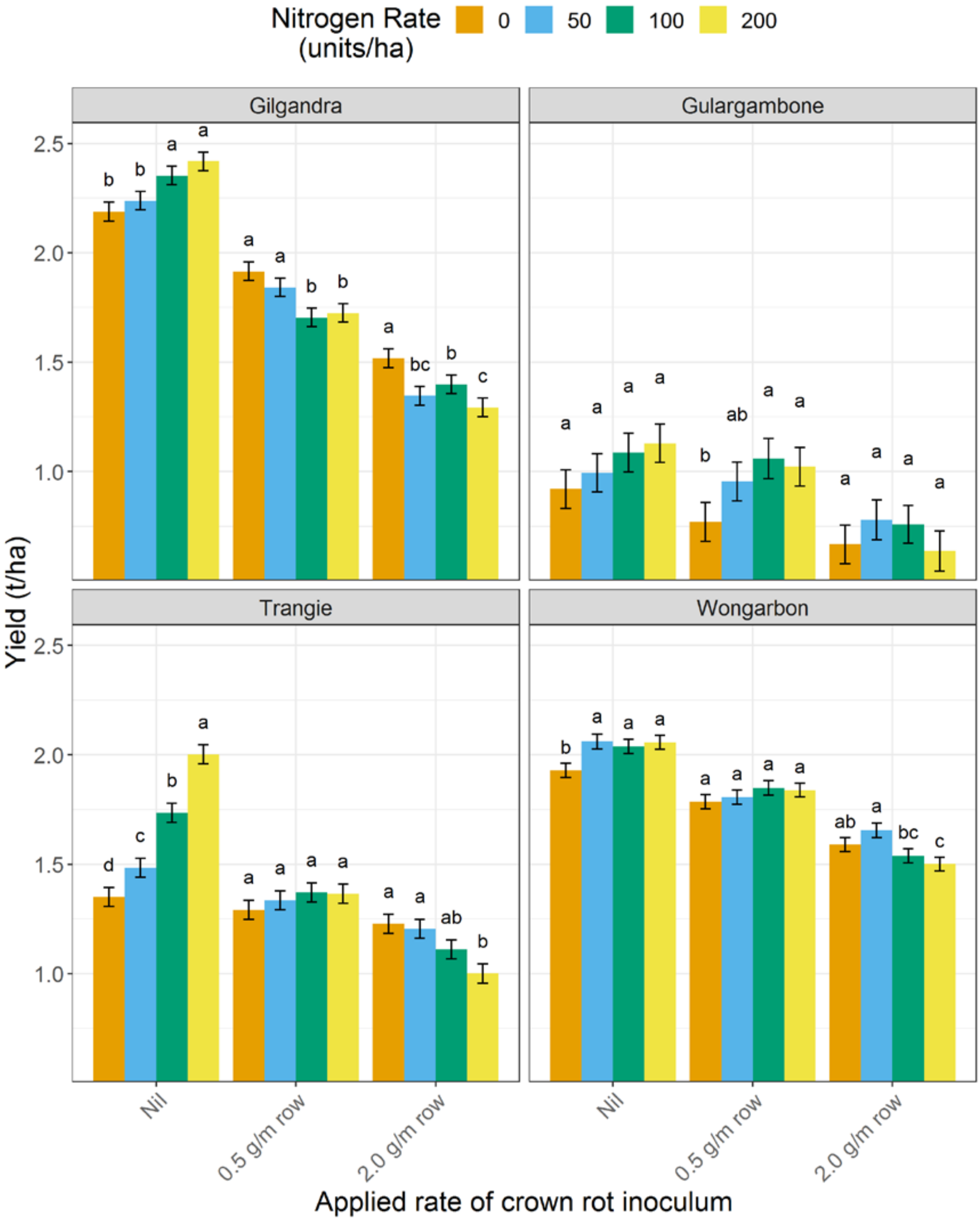

Figure 1. Interaction of nitrogen nutrition and crown rot infection on bread wheat (SuntopⓅ and EGA GregoryⓅ) yield across four sites in central NSW in 2018.
Note: Nil applied inoculum represents a BDL/low risk, 0.5 g/m row a medium risk and 2.0 g/m row a high risk of crown rot infection

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) No added CR	Yield (t/ha) Added CR	Yield loss (%)	Screenings (%) No added CR	Screenings (%) Added CR	Lost income from crown rot ($/ha)	Income added CR ($/ha)
Barley	**La Trobe**ⓓ		4.17	3.59	14.0	6.5	8.4	128	790
	Spartacusⓓ		4.18	3.58	14.3	2.9	4.6	131	788
	Commanderⓓ		4.09	3.40	16.8	6.1	8.2	151	748
	Compassⓓ		4.20	3.39	19.4	2.1	2.9	179	745
Durum	**Lillaroi**ⓓ		3.79	3.00	20.8	3.2	5.9	275	1050
	Bindaroiⓓ		3.88	2.92	24.7	2.7	5.8	336	1023
	Jandaroiⓓ		3.48	2.64	24.3	4.1	9.2	296	923
	Caparoiⓓ		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	**Beckom**ⓓ	**AH**	4.57	3.94	13.9	8.8	12.7	153	944
	Mustangⓓ	**APH**	4.17	3.67	11.9	5.2	7.0	148	1102
	Mitchⓓ	**AH**	4.08	3.51	13.9	7.7	10.2	136	842
	Reliantⓓ	**APH**	4.18	3.50	16.3	5.3	8.1	204	1051
	Suntopⓓ	**APH**	3.99	3.46	13.3	7.3	9.6	160	1037
	Sunguardⓓ	**AH**	3.81	3.35	12.0	6.2	8.7	110	804
	Spitfireⓓ	**APH**	3.86	3.34	13.3	5.8	8.0	154	1003
	Gauntletⓓ	**APH**	3.92	3.29	16.1	4.4	7.0	189	987
	Lancerⓓ	**APH**	3.88	3.27	15.8	4.8	7.1	184	981
	Sunmateⓓ	**APH**	4.02	3.23	19.6	6.4	9.7	237	969
	Coolahⓓ	**APH**	4.03	3.21	20.4	5.8	9.4	247	962
	Flankerⓓ	**APH**	4.04	3.12	22.8	6.0	10.4	277	936
	Dartⓓ	**APH**	3.73	2.99	19.9	9.3	12.8	223	897
	EGA Gregoryⓓ	**APH**	3.90	2.89	25.9	6.7	11.4	303	868
	Vikingⓓ	**APH**	3.48	2.89	17.1	10.9	16.8	179	866
	Lincolnⓓ	**AH**	3.88	2.78	28.3	8.6	12.8	264	668
	Crusaderⓓ	**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
	Suntimeⓓ	**APH**	3.43	2.62	23.6	10.6	17.2	243	787
	Strzeleckiⓓ	**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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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.

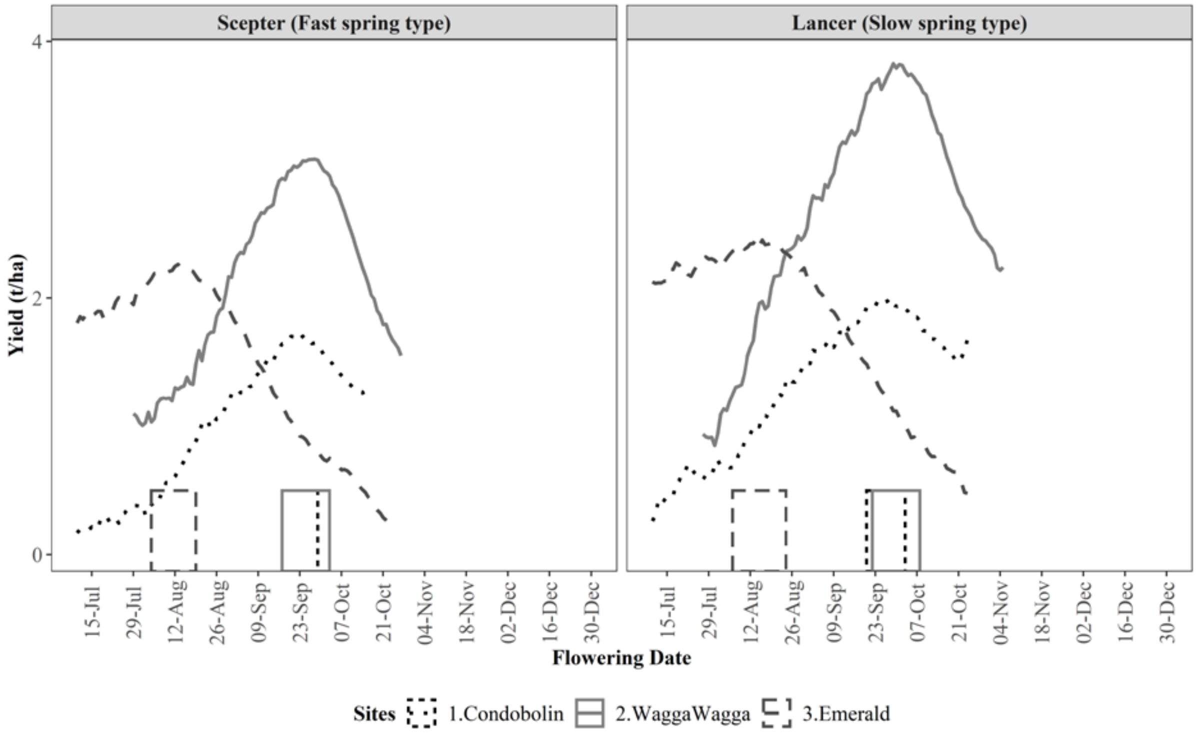

Figure 1. The optimal flowering period (OFP) for a fast spring variety (Scepter) and a slow spring variety (Lancer) determined by combining field data from experiments (2017-2019) and APSIM simulation using methods of Flohr et al. (2017) for Condobolin, Wagga Wagga and Emerald. The lines represent frost 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, Kittyhawk and Longsword) 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) 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).

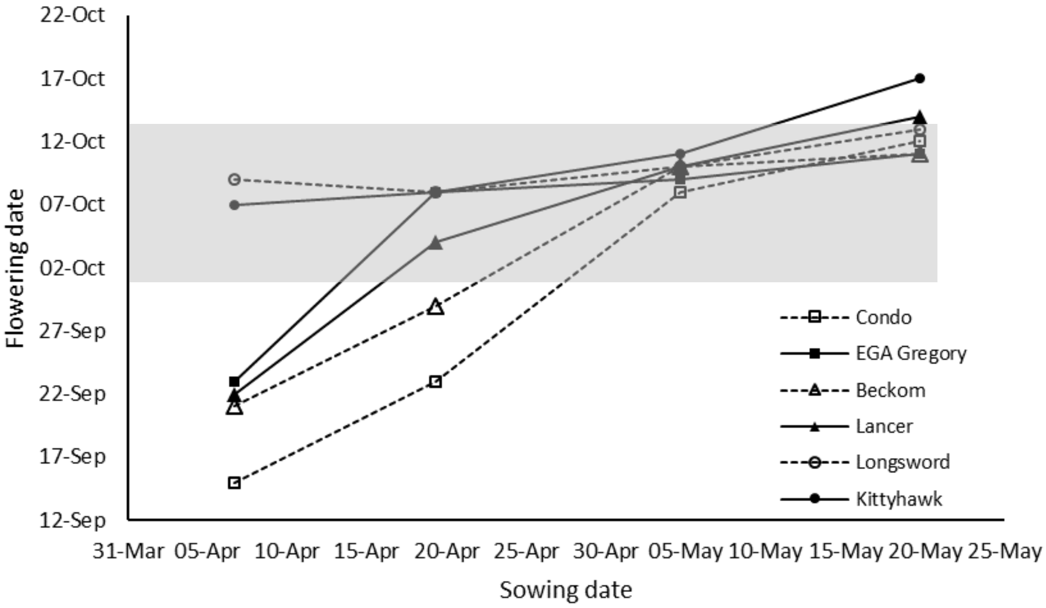

Figure 2. Mean heading date responses from selected winter and spring cultivars at Wagga Wagga (2017-18) and Marrar (2019) across all sowing times. Shaded area represents the optimal flowering period

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).

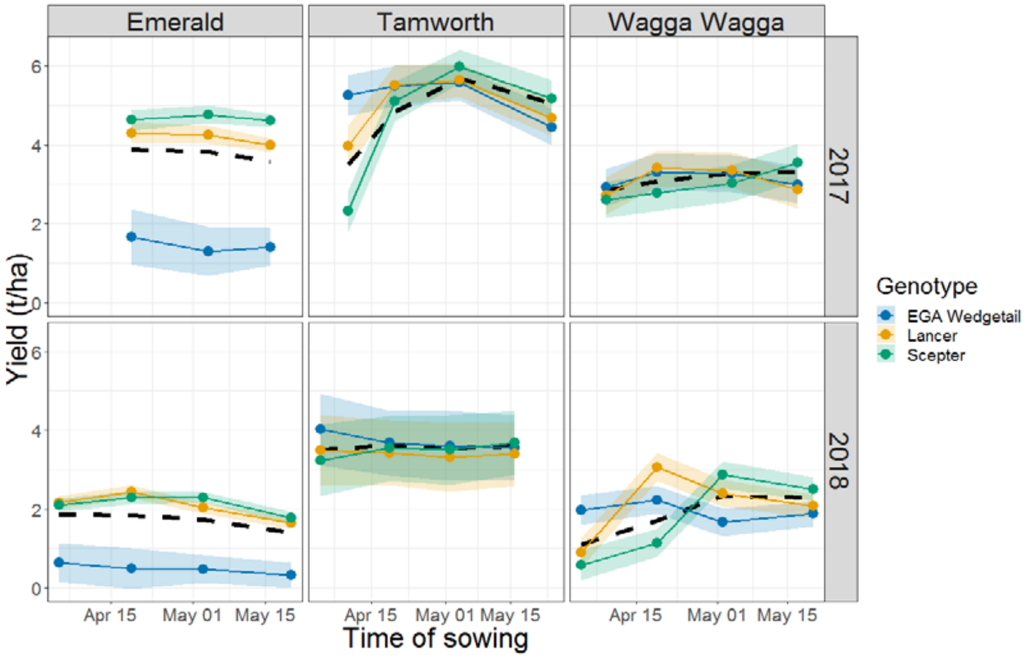

Figure 3. Predicted grain yield responses across sowing dates from early-April to late-May at Emerald, Tamworth and Wagga Wagga sites in 2017 and 2018 for selected genotypes; EGA Wedgetailⓟ (winter type), Lancerⓟ (mid spring type), Scepterⓟ (fast spring type)

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.

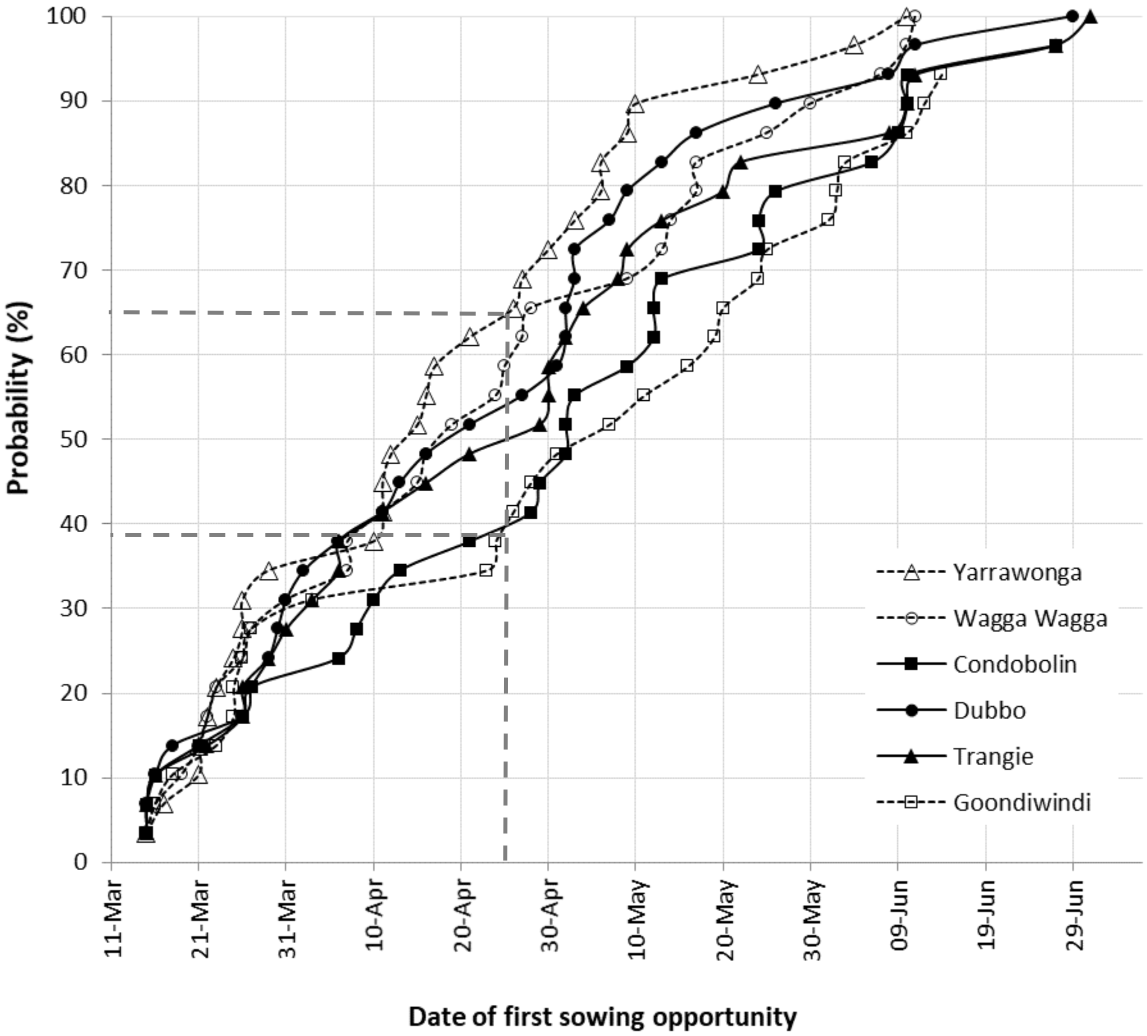

Figure 4. Probability distribution of first sowing opportunity for sites across the Northern grains region from 2000-2018 using the methods of Unkovich (2010). The dashed grey line pinpoints the probability of the sowing opportunity prior to 25 April for Condobolin and Yarrawonga

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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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).

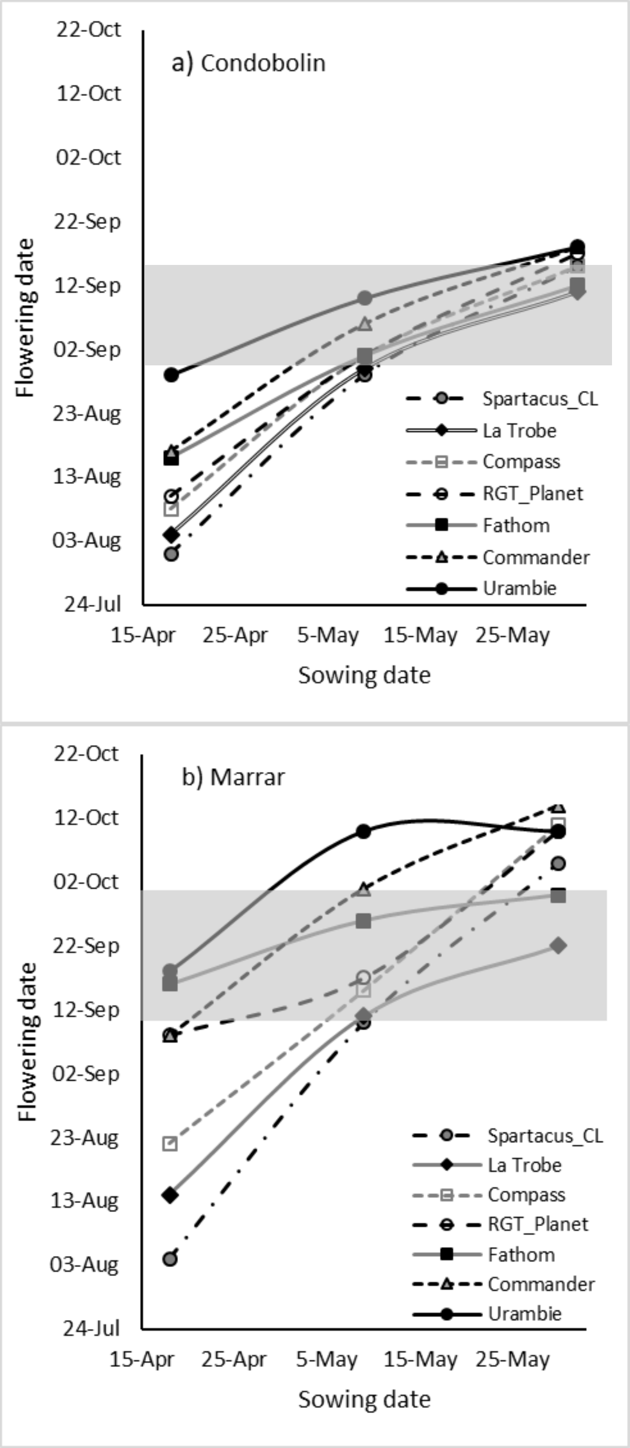

Figure 1. Flowering date responses to sowing date for selected varieties at a) Condobolin and b) Marrar field experiments in 2019. Shaded area indicates proposed optimal flowering period (OFP) at each location

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**
Banks⌽ *(Mid spring)*	3.54	3.13	2.14	3.53	3.35	2.80
Biere⌽ *(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
Commander⌽ *(Mid spring)*	3.73	2.35	1.86	3.62	3.00	2.43
Compass⌽ *(Fast spring)*	4.00	2.99	2.56	3.96	3.09	3.03
Fathom⌽ *(Mid-fast spring)*	3.80	3.07	2.54	4.57	3.58	3.00
La Trobe⌽ *(Fast spring)*	4.05	2.90	2.54	4.28	3.42	2.69
RGT Planet⌽ *(Mid-fast spring)*	4.02	2.38	1.90	3.07	2.87	2.60
Rosalind⌽ *(Fast spring)*	3.54	2.71	2.93	4.06	3.76	3.07
Spartacus CL⌽ *(Fast spring)*	3.64	3.44	2.42	4.06	3.95	2.97
Traveler⌽ *(Slow spring)*	3.41	2.69	1.83	3.21	3.39	2.52
Urambie ⌽ *(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).

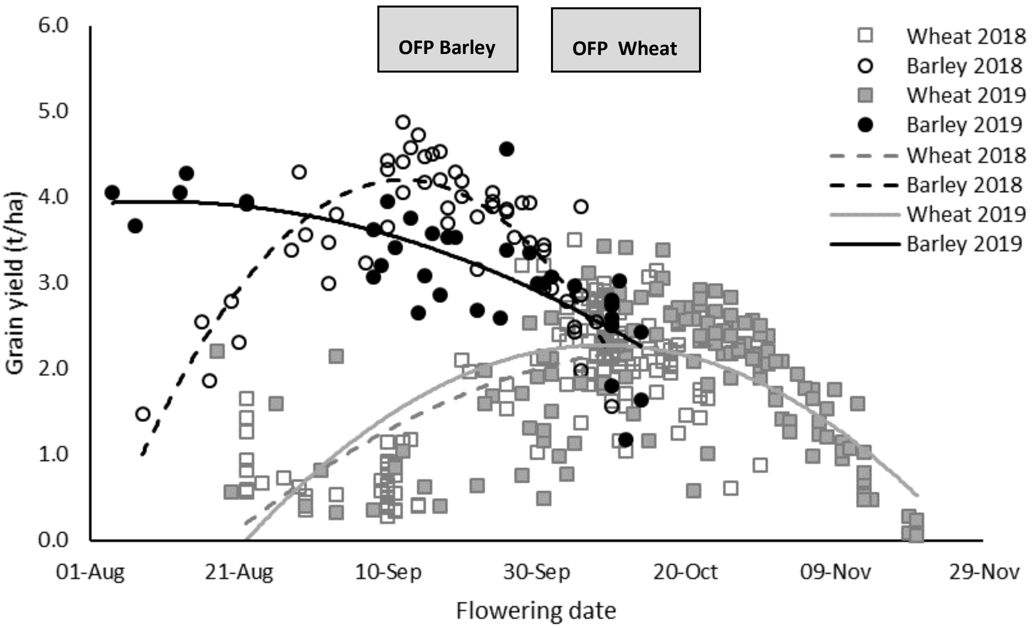

Figure 2. Grain yield responses to flowering date for a range of wheat and barley varieties sown from early April-late May in co-located experiments conducted at Wagga Wagga (2018) and Marrar (2019)

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.

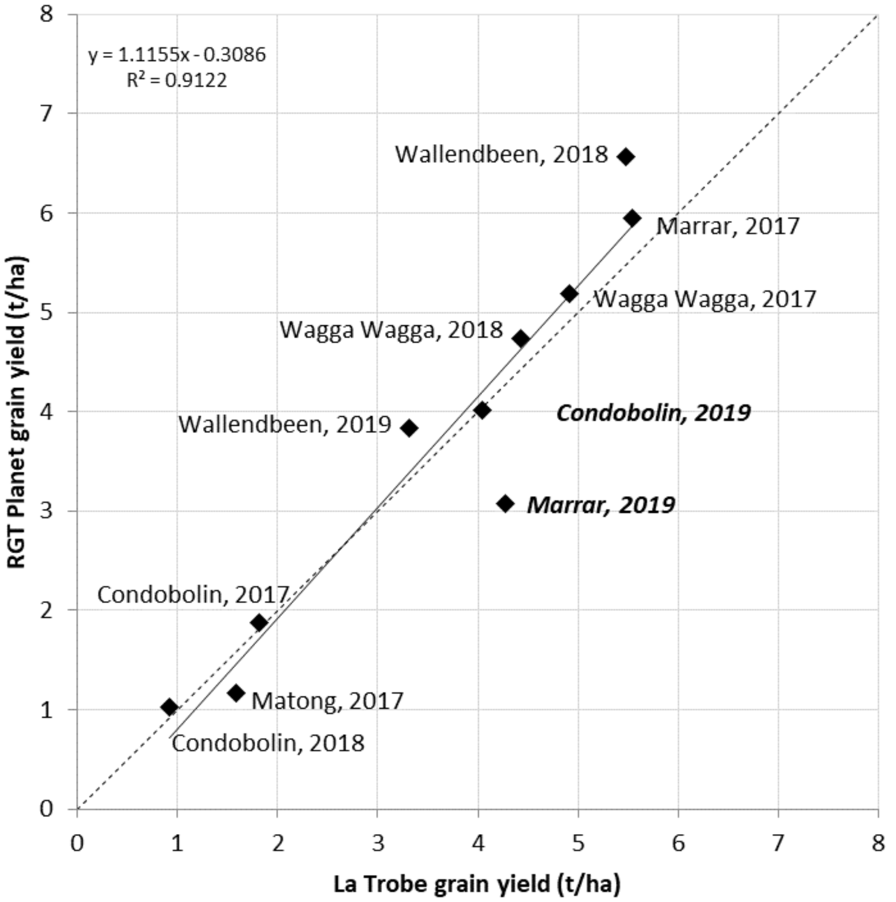

Figure 3. The relationship between highest yields of RGT Planetɸ and La Trobeɸ from field experiments at Condobolin (2017-19), Matong (2017), Wagga Wagga (2016-18), Marrar (2019) and Wallendbeen (2018-19). Dotted line indicates 1:1 relationship

Varietal differences have been observed under high frost risk seasons, such as those experienced at Wagga Wagga in 2018, whereby RGT Planetɸ was better able to maintain yield under frost conditions (SD1) compared to La Trobeɸ (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.

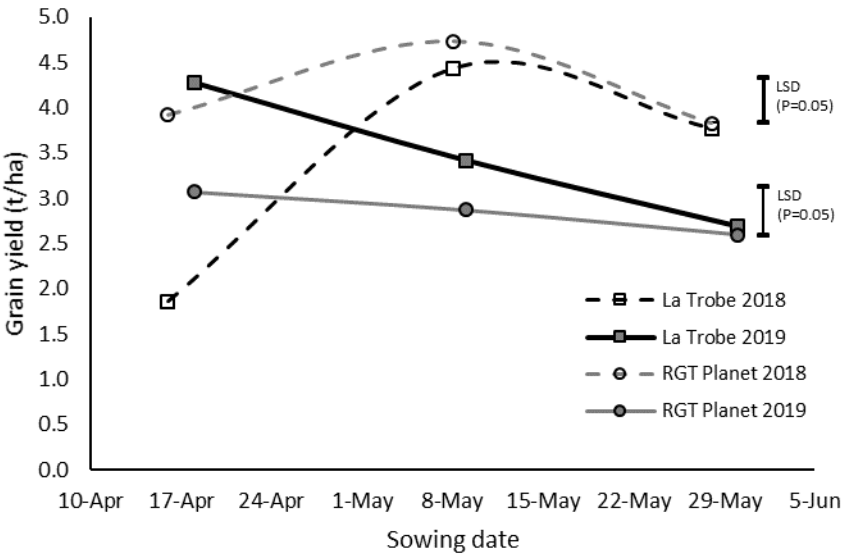

Figure 4. Grain yield responses to sowing date for RGT Planet⦷ and La Trobe⦷ at Wagga Wagga (2018) and Marrar (2019)

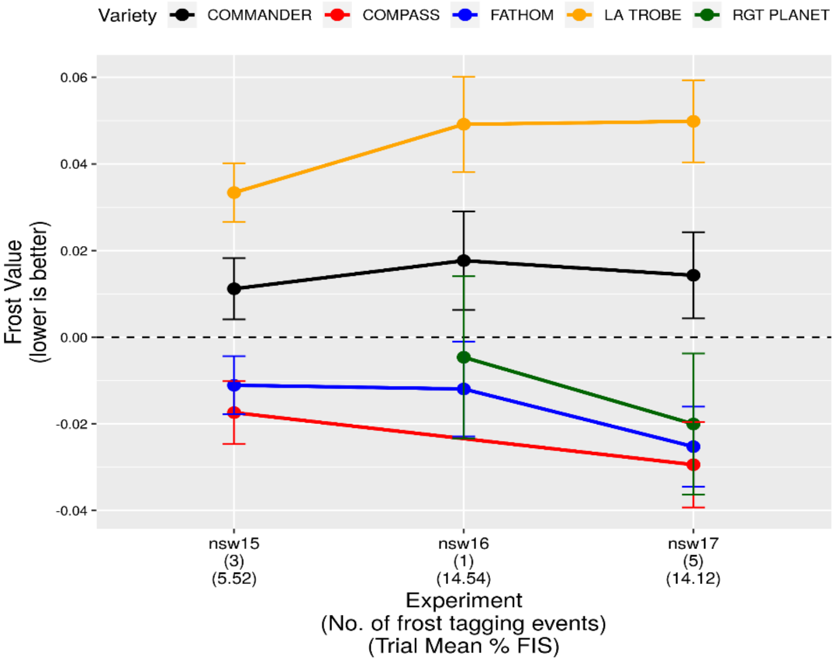

Figure 5. National Frost Initiative (NFI) variety rankings for selected barley varieties in northern region, based on experiments conducted in NSW (2015-2017)
Source: https://www.nvtonline.com.au/frost/

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/

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2020 cropping – the farmer perspective

Breil Jackson, grower, NSW

Take home messages

- Aim for the biggest return, lowest cost, least risk
- As dryland cropping farmers, we are in the business of turning rainfall into money. After three years of drastically below average rainfall, our business model is severely compromised! In fact, 2019 had the lowest March to September rainfall on record
- Access to working capital is a big factor in decision making. We cannot afford another “no-profit” season. 2020 must pay.

Fertiliser strategies

There should be a focus on extracting maximum production from the minimum input. Fertiliser application should concentrate on phosphorus, that is, MAP. The best return from fertiliser comes from the first amount applied, even if those amounts are relatively small. A very advantageous response from phosphorus fertiliser comes from placement with the seed at sowing. Often, even adequate phosphorus soils produce a profitable P response from such application. If the season starts to go well, that is, the risk of failure reduces, we can add nitrogen as the budget allows, and chase maximum production.

Crop selection

I am inclined to focus on cereals in 2020. They are the cheapest to grow, they are very reliable, grow well in bare soil, provide the fastest path to ground cover, and can be grazed or cut for hay if the season is poor, still providing income.

I would avoid high input crops at scale, such as canola – too expensive to do well, and if anything happens with the season such as poor finish, late frost, it’s a big loss we can’t afford.

I would also not be going too hard at chickpeas. I see them as a high risk crop. They are dependent on AMF (VAM) and long fallow disorder could be an issue in most crop paddocks this year. Chickpeas are vulnerable to chemical residues. They have a high seed cost and leave virtually no ground cover. Also, if the season is wet, which after three dry years, it could be, chickpeas encounter a lot of problems. Disease, chemical shortages, cost of fungicides, etc, and ability to apply them in the wet. Wet harvest leads to seed splitting and grain dockages. Too many problems = high risk crop.

In my mind, a mix of wheat, barley and oats, as the bulk of the crop, will be the most reliable profit driver to get the cropping system back in order for the lowest cost in 2020.

Herbicide residues

We must be aware of previously applied residual herbicides, especially sulfonylurea (SU) herbicides (Ally®, Logran®, Glean®, etc.). Balance can also cause issues. Most need rainfall to breakdown, and there has not been much of that. It will be especially an issue on heavier alkaline soils. Soil test, or a “pot test” might be the best bet on suspect paddocks, however false negatives can occur, as SU symptoms can be slow to appear, and/or the herbicide might be deeper in the profile and not affect the crop until later in the season. If in doubt, go for a crop that is tolerant of the herbicide residue you have concerns about.

Weed resistance

With all the fodder that has been bought into the district in recent years, one must also be well aware of new weed seeds, or indeed weed seeds that are chemical resistant. Prime source locations would be SA and WA, but weed resistance can come from anywhere. Everyone should monitor places bought in hay has been fed out for problems in this area.

Risk management

Base decisions on the rain you have had, not the rain you think you will get.

Wait till it rains before you sow, or at least don't plant big areas dry, on a whim without rain. Higher risk strategies might be more acceptable in other years, but after three years of near zero dryland production, we cannot afford another failure. I would limit or eliminate the area of high risk crops. I would limit the area of high input crops. Maximise the area of high flexibility crops, that is, those that offer grain/ or hay/ or grazing/ and or groundcover. Keep inputs low at least until the season unfolds. It is also worth noting that doing nothing is also a high risk option, (because it guarantees no income), unless it does not rain at all. Then, as in 2019, it becomes the best option!

Conclusion

It is a season for low input, low risk crops and strategies that offer maximum flexibility.

Every drought has broken and this one will break too. Long droughts are rare, and mostly they break in the autumn.

It is only production that will generate income and pay off debt. So in 2020, a focus on low cost, low risk production is our way out. If this season turns out a good one, we must extract everything we can from it, so don't be afraid to chase it with extra inputs, (nitrogen) if it's on.

Remember, yield is the key driver of profit in the dryland cropping system. As croppers at Nyngan, we make 60% of our money, in 30% of the years, so if it's a 30% year, we must not miss out.

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Dealing with the drought and planning for recovery

Discussion session

Notes

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