CAPELLA – WEDNESDAY 27TH
MOURA – THURSDAY 28TH
NOVEMBER 2019

GRAINS RESEARCH UPDATE

DRIVING PROFIT THROUGH RESEARCH

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

Welcome to the 2019 GRDC Grains Research Updates

Growers, advisers and industry stakeholders are constantly faced with challenges to farm profitability and productivity, which makes staying informed about the latest research and development outcomes a critical part of being in business.

Keeping growers and advisers informed is the key role of the annual Grains Research and Development Corporation (GRDC) Grains Research Updates, which are premiere events on the northern grains industry calendar and bring together some of Australia's leading grain research scientists and expert consultants.

For more than 25 years the GRDC has been driving grains research capability and capacity with the understanding that the continued viability of the industry hinges on rigorous, innovative research that delivers genuine profit gains. GRDC's purpose is to invest in research, development, and extension (RD&E) to create enduring profitability for Australian grain growers.

Despite the tough seasonal conditions currently being experienced across much of the Queensland and New South Wales grainbelts, the industry remains confident about the future and committed to learning more about innovation and technology and embracing practice change that has the potential to make a tangible difference to on-farm profits.

In response, this year's GRDC Grains Research Updates offer regionally relevant, credible and new science-based information covering priority issues like climate and environmental variability, new technology and market conditions to ensure growers and their advisers have up-to-date knowledge to make informed decisions on-farm.

So, I hope you enjoy the 2019 Updates and that the events provide an invaluable opportunity for learning, knowledge sharing and networking.

Luke Gaynor,

GRDC Senior Manager Extension and Communication

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& DEVELOPMENT
CORPORATION

CAPELLA

GRDC Grains Research Update
Wednesday 27 November 2019
Capella Cultural Centre

AGENDA *Registration: 8:30am for a 9:00am start, finish 3:00pm* Time	Topic	Speaker(s)
9:00 am	GRDC Welcome	
9:10 am	**How has the CQ climate changed and what impact has it had on summer crop productivity and how can we manage this issue?** BOM climate guides for Central Queensland.	Jeremy Whish *(CSIRO)*
9:45 am	**New frontiers in cereal breeding for a changing climate.** Would you like a long coleoptile wheat that competes better with weeds and tolerates a hot finish?	Greg Rebetzke *(CSIRO)*
10:15 am	**Cover crops to increase fallow efficiency**. Soil water, health, nutrition and crop performance.	Andrew Erbacher *(DAF Qld)*
10:40am	**MORNING TEA**	
11:10 am	**Modifying variety with frost risk down slope - how big are the potential yield gains and why?**	Matt Gardner *(AMPS Research)*
11:35 am	**Time of sowing (TOS) of cereals - drivers of phenology and matching variety to TOS in different environments.**	Darren Aisthorpe *(DAF Qld)*
12:00 pm	**Chemical residues/MRL's - impact, understanding and potential trade issues.**	Gordon Cumming *(GRDC)*
12:25 pm	**LUNCH**	
1:15 pm	**Farming systems - GM and $ return/mm water.** o Which systems make money in different environments and why? o N removal and needs in different crops and N use efficiency between farming systems o Water use and infiltration	Darren Aisthorpe (*DAF Qld*)
1:50 pm	**Nutritional strategies to support CQ farming systems.** o P timing, placement and implications for N timing, rate and placement. o Managing N: N movement, location, timing and budgeting. o Why are recovery efficiencies so low and how does this affect strategy for use of our single largest input cost?	Richard Daniel *(NGA)* Doug Sands & Darren Aisthorpe *(DAF Qld)*
2:25 pm	**Panel discussion - managing nutrition for the 2020 summer crop.** Timing, rates, placement and testing.	Brian Gregg *(Kolara Farming)* Doug Sands *(DAF Qld)* & Richard Daniel *(NGA)*
3:00 pm	**CLOSE**	

MOURA

GRDC Grains Research Update
Thursday 28 November 2019
Moura Tavern

AGENDA

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

Time	Topic	Speaker(s)
9:00 am	GRDC Welcome	
9:10 am	**How has the CQ climate changed and what impact has it had on summer crop productivity and how can we manage this issue?** BOM climate guides for Central Queensland.	Jeremy Whish *(CSIRO)*
9:45 am	**New frontiers in cereal breeding for a changing climate.** Would you like a long coleoptile wheat that competes better with weeds and tolerates a hot finish?	Greg Rebetzke *(CSIRO)*
10:15 am	**Modifying variety with frost risk down slope - how big are the potential yield gains and why?**	Matt Gardner *(AMPS Research)*
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12:05 pm	**Farming systems - GM and $ return/mm water.** o Which systems make money in different environments and why? o N removal and needs in different crops and N use efficiency between farming systems o Water use and infiltration	Darren Aisthorpe *(DAF Qld)*
12:40 pm	**LUNCH**	
1:25 pm	**Cover crops to increase fallow efficiency:** soil water, health, nutrition and crop performance.	Andrew Erbacher *(DAF Qld)*
1:50 pm	**Local experience using cover crops.**	*Jeff York (Acres Rural Supplies)*
2:10 pm	**Mungbean agronomy update for the Dawson Callide -** time of sowing, plant population and row spacing +/- irrigation.	Doug Sands *(DAF Qld)*
2:40 pm	**Making money from mungbeans – a growers perspective.**	Lee Jones *('The Crescent')*
3:00 pm	**CLOSE**	

Contents

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How has Central Queensland climate changed and what impact has it had on sorghum productivity (Capella)

Jeremy Whish and Elizabeth Meier (CSIRO)

Key words

climate, historic climate, changing yield potential, sorghum

GRDC code

CSP1806-01

Take home message

- Increasing temperatures and reduced rainfall have lowered the yield potential of sorghum in many areas
- Avoiding high temperatures at flowering and using a conservative sowing trigger (>100mm) can reduce the impact of a changing climate
- There is still room to reduce the yield gap with targeted sowing dates, nitrogen rates and soil water triggers despite a changing climate reducing sorghum yield potential

Introduction

Australia's climate is warming, including an increase in average temperature, increase in number of days exceeding 35°C and a decrease in rainfall (CSIRO and BOM, 2015).

But what is happening at Capella? How will this affect the crops I grow? What can I do to manage this change?

These are some of the questions we have tried to address in this study.

Over the last few years, several suggestions have been made to GRDC that have warranted our examination of sorghum production in response to changing climates. The key concern was that a changing climate had reduced the yield potential of central Queensland crops and would cause the key sorghum production areas to move south to cooler and less variable climates. In this paper we review local annual and growing season climates, sorghum production and compare these results to other sorghum production areas to see how or if things have changed.

Methods

Current climate was compared with historical climate using a 'climate normal' approach to compare overlapping 30-year time periods. This is recognised as the most statistically sound method to determine if a change in climate has occurred (Arguez and Vose, 2011) and is recommended by the World Meteorological Organisation's standard for placing current climate conditions in a historical perspective. A simulation analysis of sorghum production in response to a range of initial soil water and sowing dates was then conducted using APSIM to identify whether changing these management practices could mitigate the effect of any changes in climate.

How is the Capella environment changing?

Rainfall

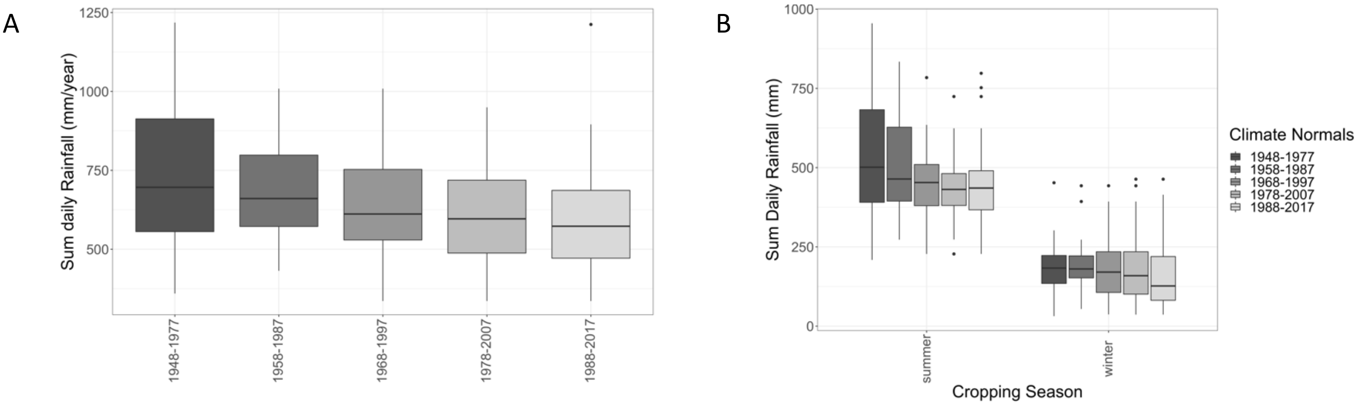


Figure 1. Sum of rainfall for each 30-year climate normal period on an annual (A) and cropping season (B) basis at Capella. The results show how rainfall has changed over time. In general rainfall has had minimal change over the study period. However, greater variability is observed in the most recent 30-year period (1988-2017) with this variability predominantly in the summer.

Temperature

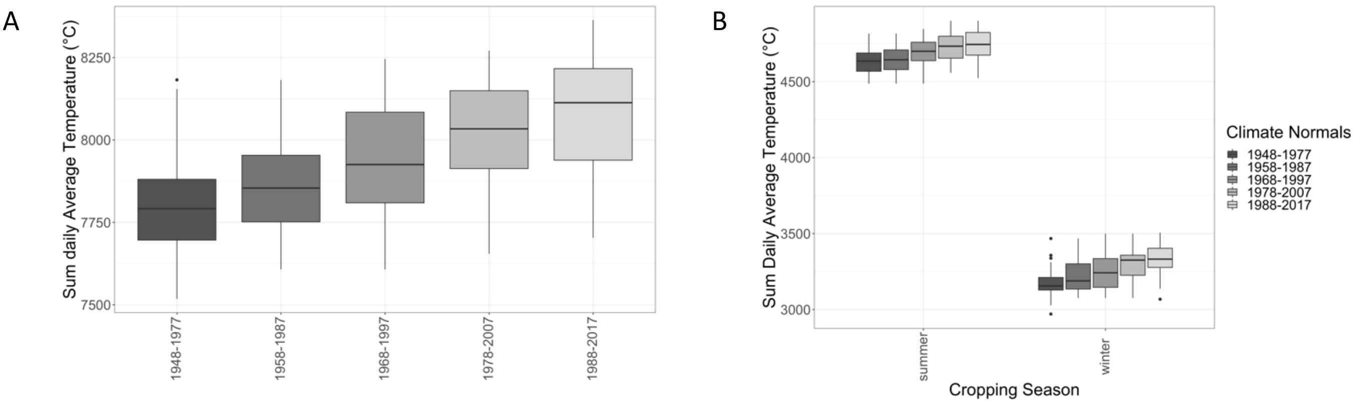
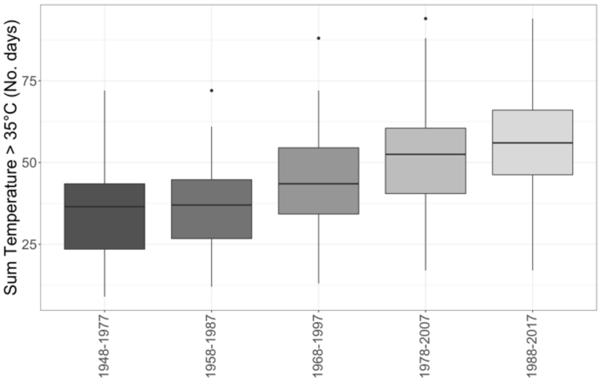


Figure 2. Sum of daily average temperature on an annual (A) and cropping season basis at Capella. Average temperature showed a continual increase in heat to the 1978-2007 normal and then levelling for the most recent climate normal (1988-2017). The change in accumulation of heat was similar in both summer and winter growing seasons.

Extreme temperatures

A



B

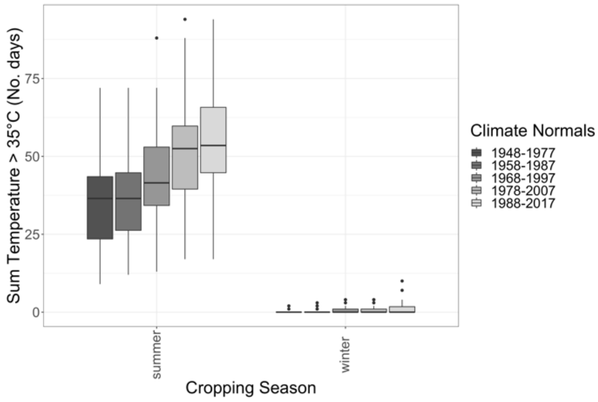


Figure 3. Number of days of extreme temperatures (above 35°C) summed on an annual (A) and growing season (B) basis. The days above 35°C follow a similar pattern to the heat sum on an annual basis increasing to the 1978-2007 normal and then plateauing. Extreme temperatures generally occur in the summer, but the number of days in winter is increasing. The final climate normal (1988-2017) like temperature and rainfall has greater variability, which supports current climate change predictions.

How will these changes in climate affect sorghum?

Higher temperatures increase the rate of crop development and the amount of water transpired by the crop. If rainfall remains stable or decreases, then this will increase the chance of moisture stress occurring in the crop. However, if the growing period of the crop can be matched to the timing of rainfall then it may be possible to maintain or increase crop grain yield despite an annual reduction in rainfall.

To identify whether the yield potential of sorghum crops had changed over the last 60 years a series of simulations was undertaken. The 60-year period from 1958-2017 was used for this analysis and sub-divided into two climate normals – 1958-1987 and 1988-2017 - that could be compared.

Water stored within the soil helps to buffer crops from variability in the climate. In order to understand the effect on yield of changes in the climate, the median yield from a crop sown into a full profile of water was compared across the 60-year period. This approach was expected to demonstrate the least difference between the two climate normal periods for effect of change in climate on crop yield because each site and sowing date combination had optimal soil water at sowing. The study was completed for a selection of locations ('transects') in both the eastern and western parts of the GRDC northern growing region (Figure 4).

Sorghum crop yields sown on a full profile of soil water

For northern sites of the western transect (from Mungindi north) there was little change in yield except for a reduction in yield of around 0.5 t/ha at the extremes of early sowing and late sowing (Figure 4). For the northern sites of the eastern transect there was a clear reduction in yield for sites north of Goondiwindi, especially for sowing dates before November. For the eastern transect there were distinct groupings of change in yield: improved yield between Goondiwindi and Moree for crops sown between November and January and decline in yield on the Liverpool Plains that worsened with later sowings and culminated around a mid-December plant.

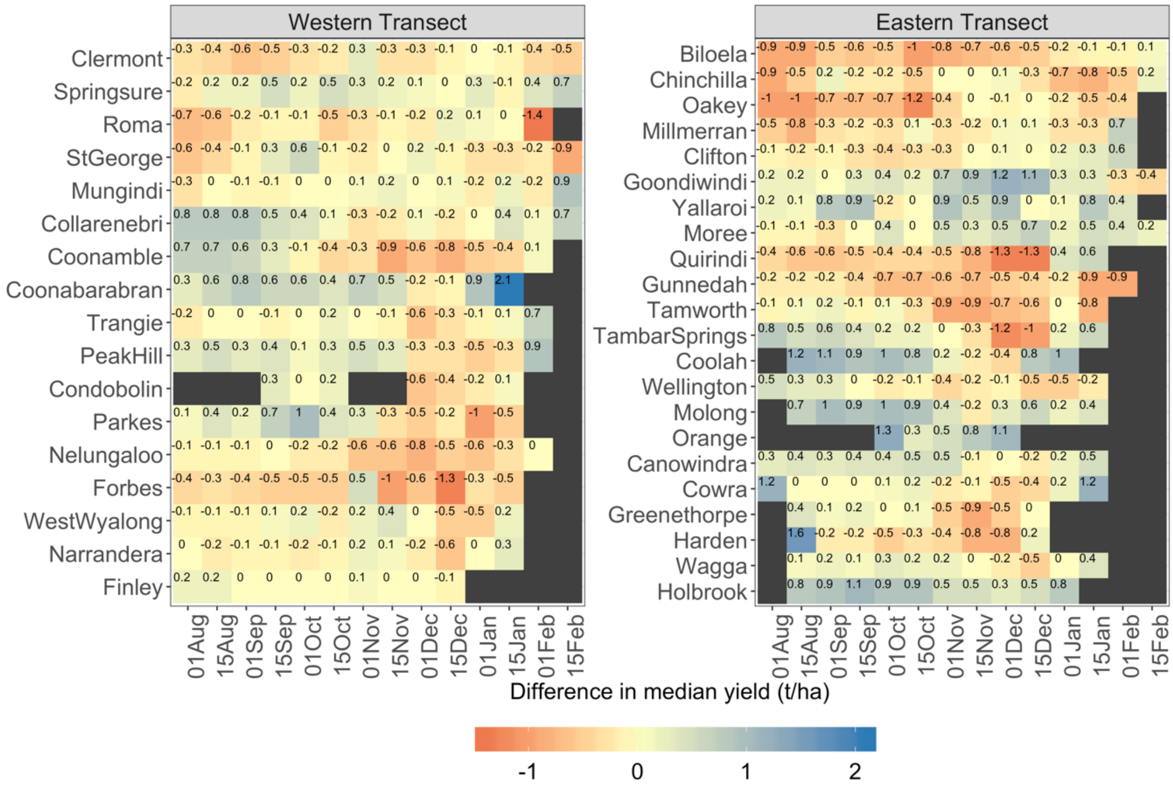


Figure 4. Difference in median yield of sorghum crops between climate normals 1958-1987 and 1988-2017 when sown into a full profile of water, for different sowing dates for locations divided into western and eastern transects. Red shading in cells indicates a decrease in yield, blue indicates an increase, and yellow indicates sowing dates where there was minimal to no difference in crop yield. Only median yields from sowing dates that had fewer than 50% failed crops are included (other location-sowing date combinations were considered unsuitable for crop production and are coloured black). Values within each cell are the difference in yield between the climate normals (t/ha).

What has been the effect of changing climate on yield when there isn't a full profile of soil water at sowing?

The objective of simulating sorghum crop yields in response to a full profile of water in the previous step above was to understand whether the most recent 30-year climate normal period was different to the previous 30-year normal in terms of its effect on crop yield. However, it is inefficient to wait for a soil profile to fill because producing adequate crops regularly can be financially better than waiting for conditions (such as a full soil water profile) that will produce potential crop yields. In this section we present results for crops sown into a profile with an initial amount of 100 mm of available soil water. This amount is towards the lower end of soil water that would be present when a decision to sow occurs (the general sowing rule for western sites is more commonly to have 150 mm of plant available water). In the eastern sites with higher rainfall as little as 50mm is used, but 100 is more common. The use of 100mm for both transects is a compromise and if sowing below this value, then agronomic factors other than initial soil water, such as row configuration (Whish et al., 2005) would be used to reduce risk (such practices are not included in this study).

There was an increase in crop failure (cells shaded black) between crops sown on a full profile of soil water (Figure 4) and those sown into a profile containing 100mm (Figure 5). This difference in initial soil water also explains the use of wide row configuration and 150 mm soil water trigger that is used by many grain growers along the western transect. However, despite these differences in yield arising from differences in initial soil water, the general patterns of changes in yield and optimal sowing dates between climate normals were the same. There were minimal differences in yield between climate normals for the north-western sites, but a decrease in yield potential for the eastern sites. The November to mid-January sowing dates between Goondiwindi and Moree continued to demonstrate an increase in yield for the more recent normal, while later sowing in the Liverpool Plains continued to demonstrate a yield reduction.

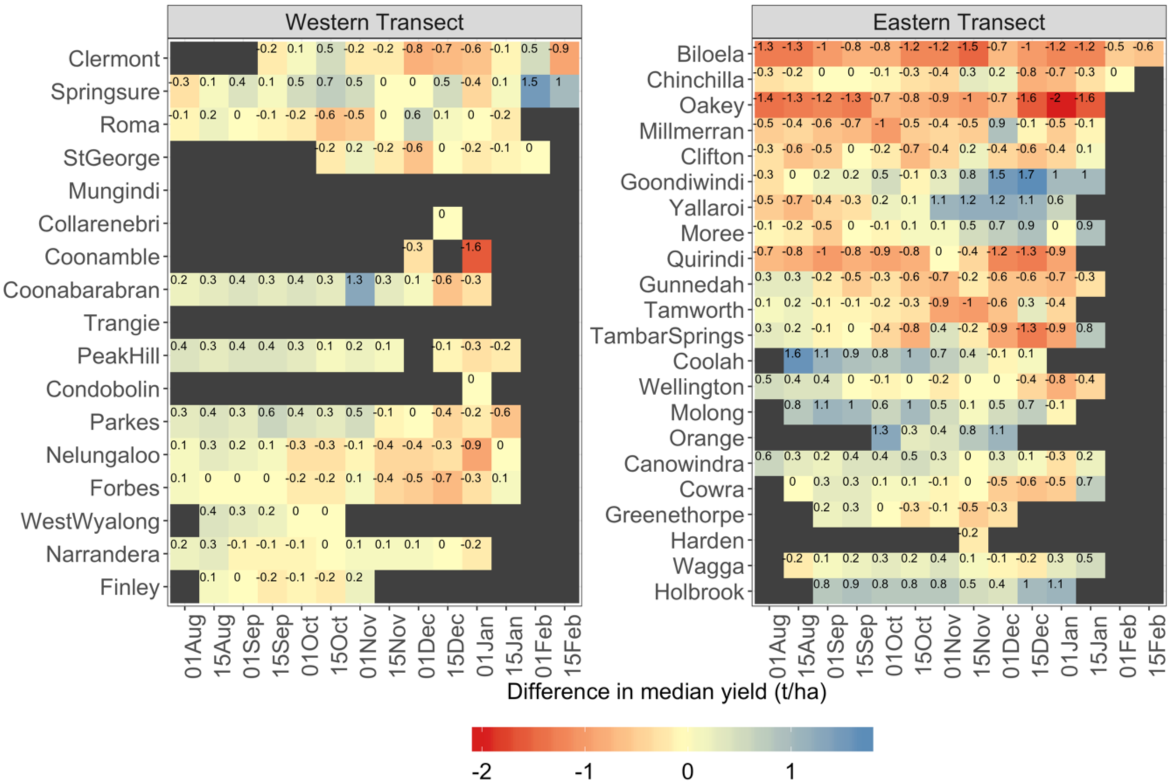


Figure 5. Difference in median yield of sorghum crops between climate normals 1958-1987 and 1988-2017 when sown into a profile of 100 mm of water, for different sowing dates for locations divided into western and eastern transects. Red shading indicates a decrease in yield, blue shading indicates an increase in yield, and yellow shading indicates sowing dates for each location with minimal to no difference in yield. Only median yields from sowing dates that had fewer than 50% failed crops are included (other location-sowing date combinations were considered unsuitable for crop production and are coloured black). The values within each cell specifies the magnitude of the difference in yield between the climate normal periods (t/ha).

Why are yields changing?

Rainfall

The availability of water to the crop is the key determinant of yield in Australia. The value of stored soil water is its ability to buffer the demands of the plant in between rainfall events and ensure optimal plant growth. The timing and size of rainfall events are critical to maintaining this buffer as is the specific soil type. In general, the quantity of in-crop rainfall decreased or remained neutral across locations in both eastern and western transects, although there was an increase in in-crop rainfall at a few locations (e.g. Coonabarabran, Goondiwindi and Yallaroi for some times of sowing). These locations are those that showed an increase in water limited yield potential (Figures 4 and 7) and highlight that this increase in rainfall pattern has directly resulted in increased yield.

For Capella lying between Clermont and Springsure the yield difference between the two time periods was neutral to slightly positive as you move south.

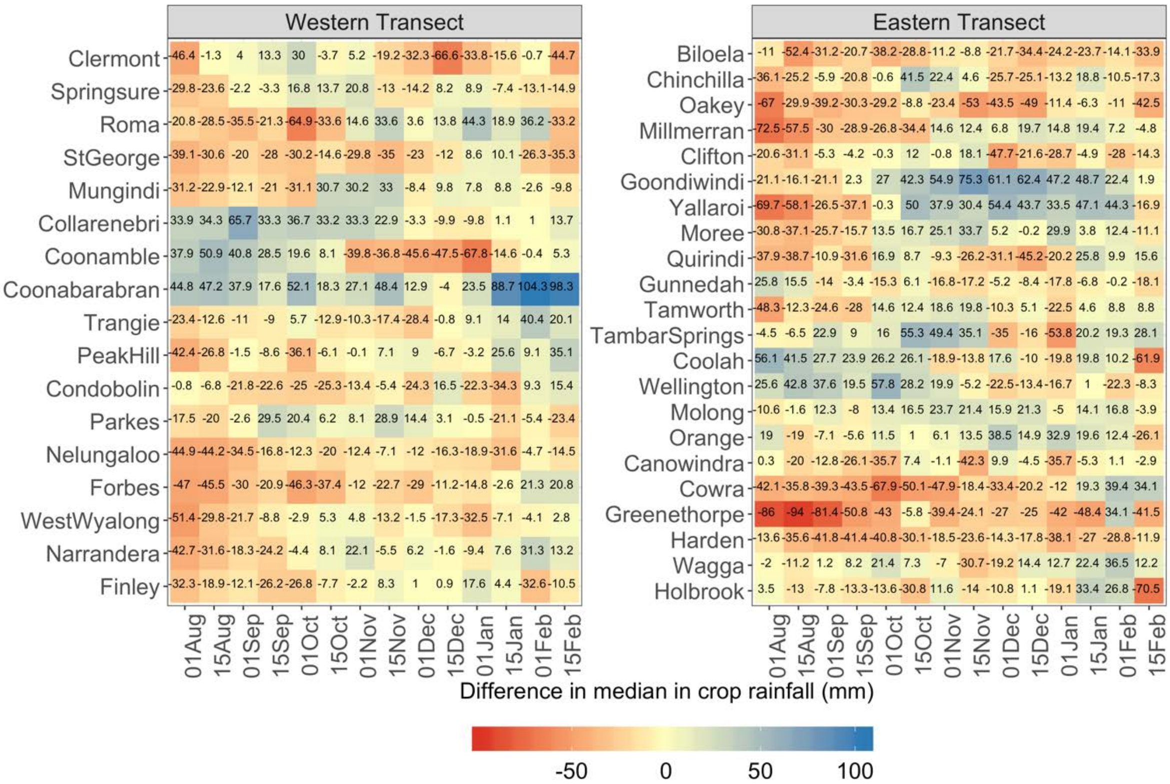


Figure 6. Difference in median in-crop rainfall for the 14 different sowing dates between the two climate periods 1958-1987 and 1988-2017, for locations in western and eastern transects. Red shading indicates a decrease in in-crop rainfall, blue shading indicates an increase in rainfall, and yellow indicates sowing dates with minimal to no difference in rainfall between normals. The values within each cell are the difference in median in in-crop rainfall (mm).

Extreme temperatures

High temperatures around flowering can significantly reduce sorghum grain yield (Lobell et al., 2015; Singh et al., 2017; 2016). The difference in the number of days with temperatures in excess of 35°C increased between the past 30-year climate normal period (1958-1987) and the more recent 30-year normal (1988-2017). The increase in days with extreme temperatures was greater for the western transect, especially for crops sown between October and November. For the eastern transect there was a general increase in the number of days with extreme temperatures for all sowing dates before December. However, a few specific sites experienced a reduction in extreme temperatures; these sites and sowing dates correspond with those that experienced an increase in rainfall and consequently an increase in median yield potential (Figure 7).

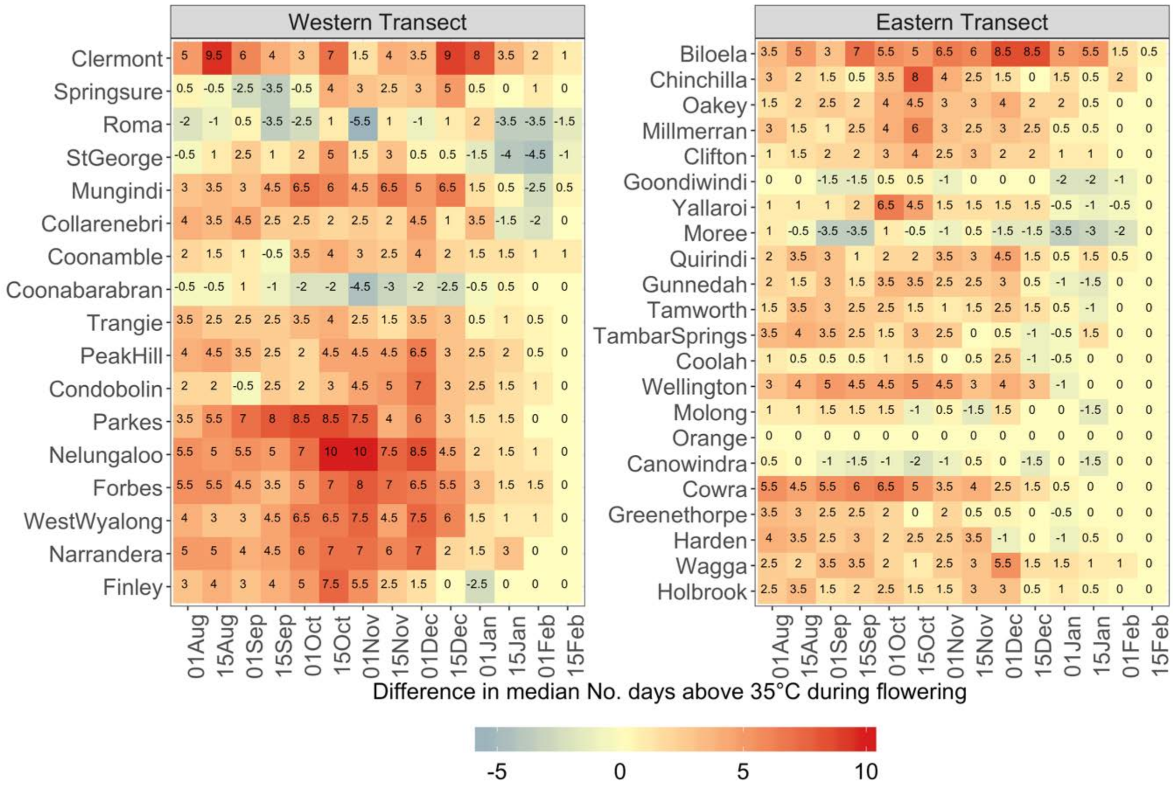


Figure 7. Difference in the median number of days above 35°C during flowering for the 14 different sowing dates between the two time periods of 1958-1987 and 1988-2017, for western and eastern transects within the northern grain zone of eastern Australia. Red indicates an increase in rainfall while blue indicates a decrease, yellow highlights those sowing dates with minimal to no difference. The values within each cell are the difference in median number of days above 35°C during flowering.

So, what does it mean and what can I do?

The climate of Australia's sorghum production area has changed, with increases in the average daily temperature, an increase in the number of days with extreme temperatures during flowering, and a decrease in in-crop rainfall for many locations. These changes have resulted in an overall reduction in crop yield potential. However, despite this decrease the yield potential has not been reduced to a point where it is no longer economical to grow sorghum. Good agronomy and the use of high soil water triggers at sowing will help maintain profitable returns under changing climates. For sites that had an increase in yield for some sowing dates, this could be traced to increased rainfall and a decrease in extreme temperatures during flowering. However, these increases were relative only to the areas historic production and not an increase above traditionally high yield regions. Thus, despite a decrease in the yield potential over the study period for many areas, this decrease was too small to cause a noticeable shift in sorghum production areas, and so NSW is not the new central Queensland for sorghum production.

References

Arguez, A., Vose, R.S., 2011. The Definition of the Standard WMO Climate Normal: The Key to Deriving Alternative Climate Normals. Bull. Amer. Meteor. Soc. 92, 699–704. doi:10.1175/2010BAMS2955.1

CSIRO and Bureau of Meteorology 2015, Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report, CSIRO and Bureau of Meteorology,

Australia.
https://www.climatechangeinaustralia.gov.au/media/ccia/2.1.6/cms_page_media/168/CCIA_2015_NRM_TechnicalReport_WEB.pdf

Lobell, D.B., Hammer, G.L., Chenu, K., Zheng, B., McLean, G., Chapman, S., 2015. The shifting influence of drought and heat stress for crops in northeast Australia. Glob Change Biol 21, 4115–4127. doi:10.1111/gcb.13022

Singh, V., Nguyen, C.T., McLean, G., Chapman, S., Zheng, B., van Oosterom, E.J., Hammer, G.L., 2017. Quantifying high temperature risks and their potential effects on sorghum production in Australia. Field Crops Research 211, 77–88. doi:10.1016/j.fcr.2017.06.012

Singh, V., Nguyen, C.T., Yang, Z., Chapman, S., van Oosterom, E.J., Hammer, G.L., 2016. Genotypic differences in effects of short episodes of high-temperature stress during reproductive development in sorghum. Crop Sci 56, 1561–1572. doi:10.2135/cropsci2015.09.0545

Whish, J.P.M., Butler, G., Castor, M., Cawthray, S., Broad, I., Carberry, P.S., Hammer, G.L., McLean, G., Routley, R., Yeates, S.J., 2005. Modelling the effects of row configuration on sorghum yield reliability in north-eastern Australia. Aust. J. Agric. Res. 56, 11–23. doi:10.1071/AR04128

Acknowledgements

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Jeremy Whish and Elizabeth Meier (CSIRO)

Key words

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GRDC code

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How is the Moura environment changing?

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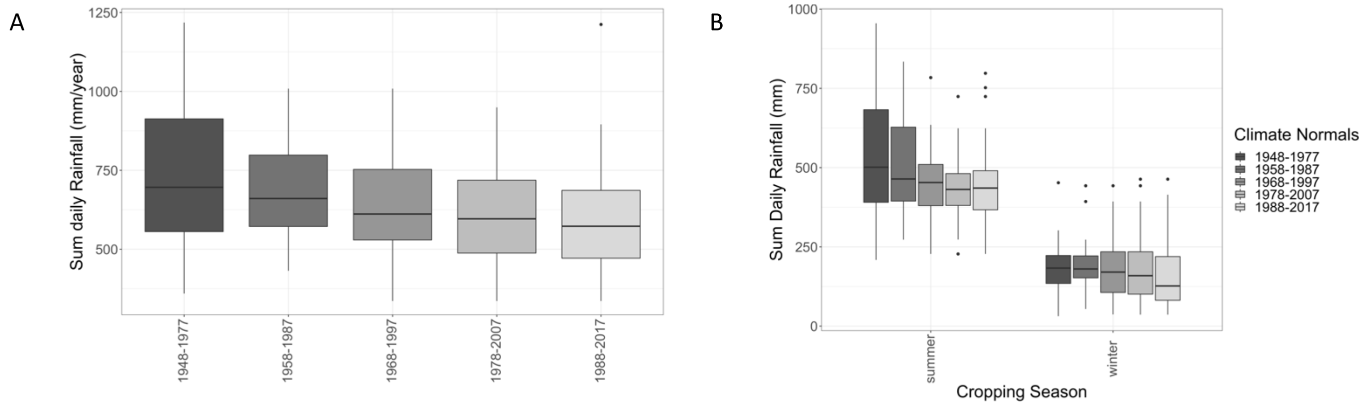

Figure 1. Sum of rainfall for each 30-year climate normal period on an annual (A) and cropping season (B) basis at Moura. The results show how rainfall has changed over time. In general rainfall has declined ($P \leq 0.5$) over the study period. The majority of this decline has been during the winter season.

Temperature

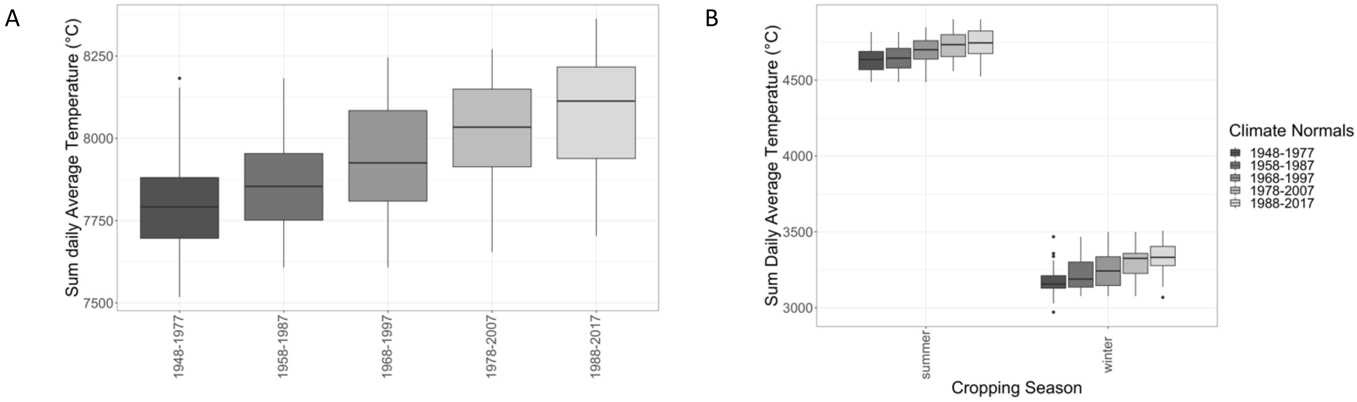

Figure 2. Sum of daily average temperature on an annual (A) and cropping season basis at Moura. Average temperature showed a continual increase in heat to the most recent climate normal (1988-2017). The change in accumulation of heat was similar in both summer and winter growing seasons.

Extreme temperatures

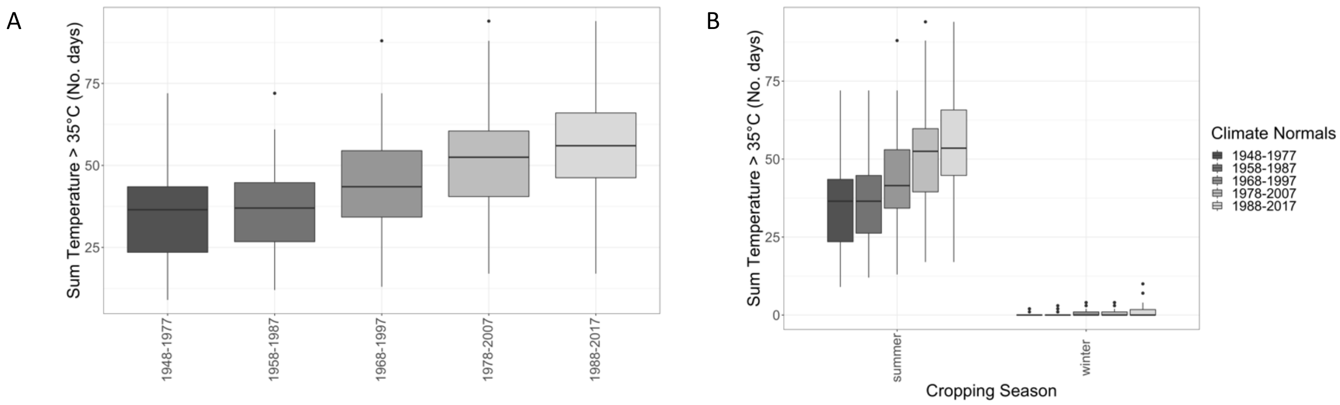

Figure 3. Number of days of extreme temperatures (above 35°C) summed on an annual (A) and growing season (B) basis. The days above 35°C follow a similar pattern to the heat sum on an annual basis increasing to the most recent normal (1988-2017). Extreme temperatures generally occur in the summer, but the number of days in winter is increasing.

How will these changes in climate affect sorghum?

Higher temperatures increase the rate of crop development and the amount of water transpired by the crop. If rainfall remains stable or decreases then this will increase the chance of moisture stress occurring in the crop. However, if the growing period of the crop can be matched to the timing of rainfall then it may be possible to maintain or increase crop grain yield despite an annual reduction in rainfall.

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Water stored within the soil helps to buffer crops from variability in the climate. In order to understand the effect on yield of changes in the climate, the median yield from a crop sown into a full profile of water was compared across the 60-year period. This approach was expected to demonstrate the least difference between the two climate normal periods for effect of change in climate on crop yield because each site and sowing date combination had optimal soil water at sowing. The study was completed for a selection of locations (‘transects’) in both the eastern and western parts of the GRDC northern growing region (Figure 4).

Sorghum crop yields sown on a full profile of soil water

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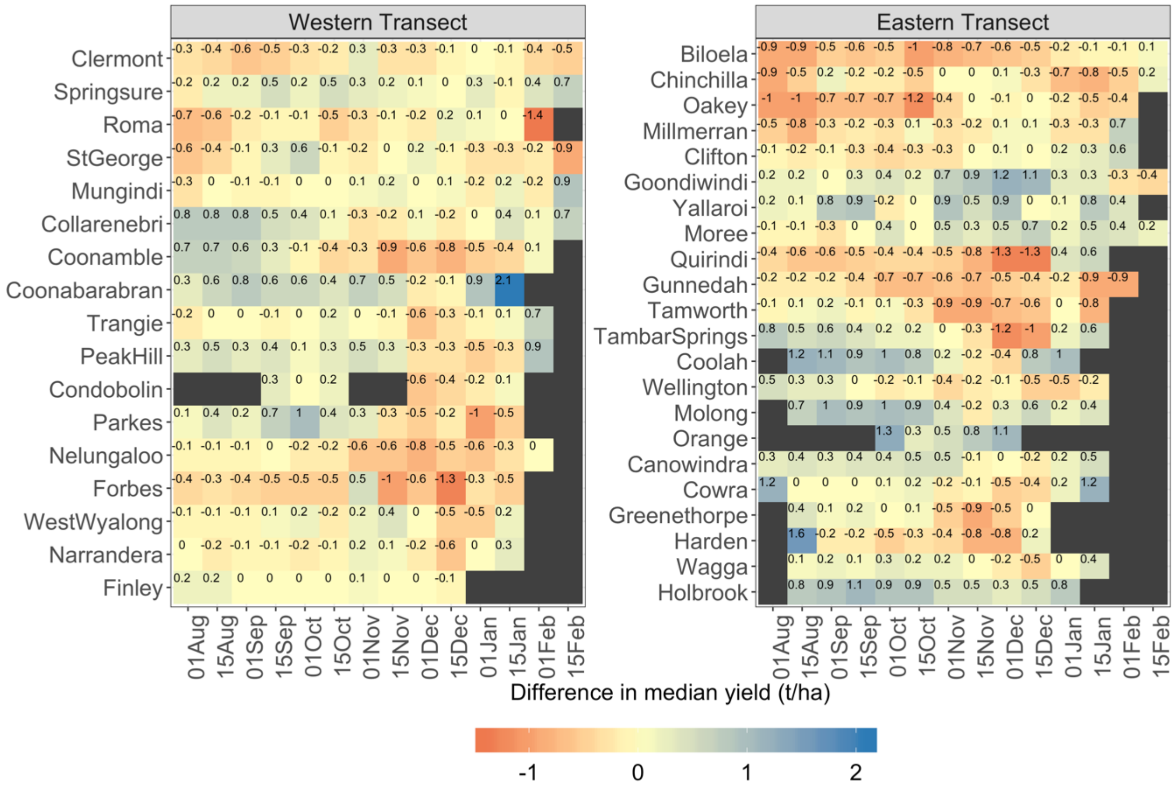

Figure 4. Difference in median yield of sorghum crops between climate normals 1958-1987 and 1988-2017 when sown into a full profile of water, for different sowing dates for locations divided into western and eastern transects. Red shading in cells indicates a decrease in yield, blue indicates an increase, and yellow indicates sowing dates where there was minimal to no difference in crop yield. Only median yields from sowing dates that had fewer than 50% failed crops are included (other location-sowing date combinations were considered unsuitable for crop production and are coloured black). Values within each cell are the difference in yield between the climate normals (t/ha).

What has been the effect of changing climate on yield when there isn't a full profile of soil water at sowing?

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There was an increase in crop failure (cells shaded black) between crops sown on a full profile of soil water (Figure 4) and those sown into a profile containing 100mm (Figure 5). This difference in initial soil water also explains the use of wide row configuration and 150 mm soil water trigger that is used by many grain growers along the western transect. However, despite these differences in yield arising from differences in initial soil water, the general patterns of changes in yield and optimal sowing dates between climate normals were the same. There were minimal differences in yield between climate normals for the north-western sites, but a decrease in yield potential for the eastern sites. The November to mid-January sowing dates between Goondiwindi and Moree continued to demonstrate an increase in yield for the more recent normal, while later sowing in the Liverpool Plains continued to demonstrate a yield reduction.

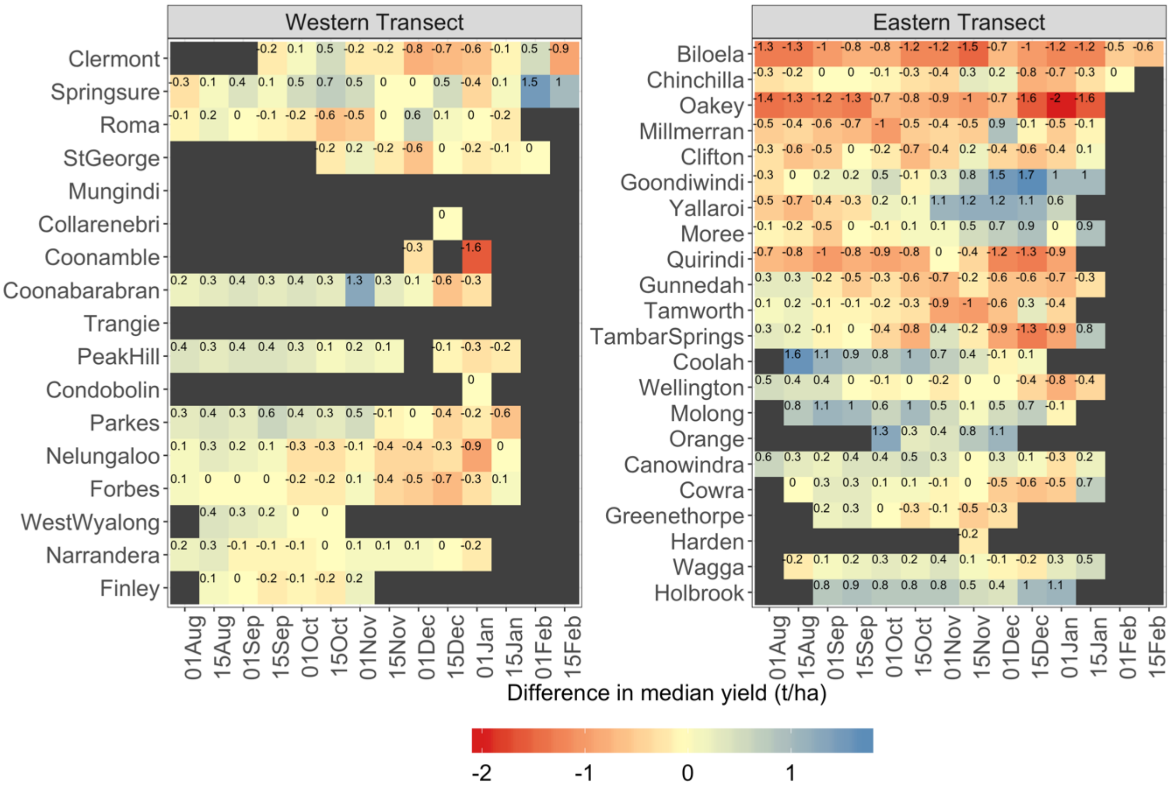

Figure 5. Difference in median yield of sorghum crops between climate normals 1958-1987 and 1988-2017 when sown into a profile of 100 mm of water, for different sowing dates for locations divided into western and eastern transects. Red shading indicates a decrease in yield, blue shading indicates an increase in yield, and yellow shading indicates sowing dates for each location with minimal to no difference in yield. Only median yields from sowing dates that had fewer than 50% failed crops are included (other location-sowing date combinations were considered unsuitable for crop production and are coloured black). The values within each cell specifies the magnitude of the difference in yield between the climate normal periods (t/ha).

Why are yields changing?

Rainfall

The availability of water to the crop is the key determinant of yield in Australia. The value of stored soil water is its ability to buffer the demands of the plant in between rainfall events and ensure optimal plant growth. The timing and size of rainfall events are critical to maintaining this buffer as is the specific soil type. In general, the quantity of in-crop rainfall decreased or remained neutral across locations in both eastern and western transects, although there was an increase in in-crop rainfall at a few locations (e.g. Coonabarabran, Goondiwindi and Yallaroi for sometimes of sowing). These locations are those that showed an increase in water limited yield potential (Figures 4 and 7) and highlight that this increase in rainfall pattern has directly resulted in increased yield.

Moura being at a similar latitude to Biloela is assumed to behave in a similar way, though being slightly west the magnitude of the differences could be less.

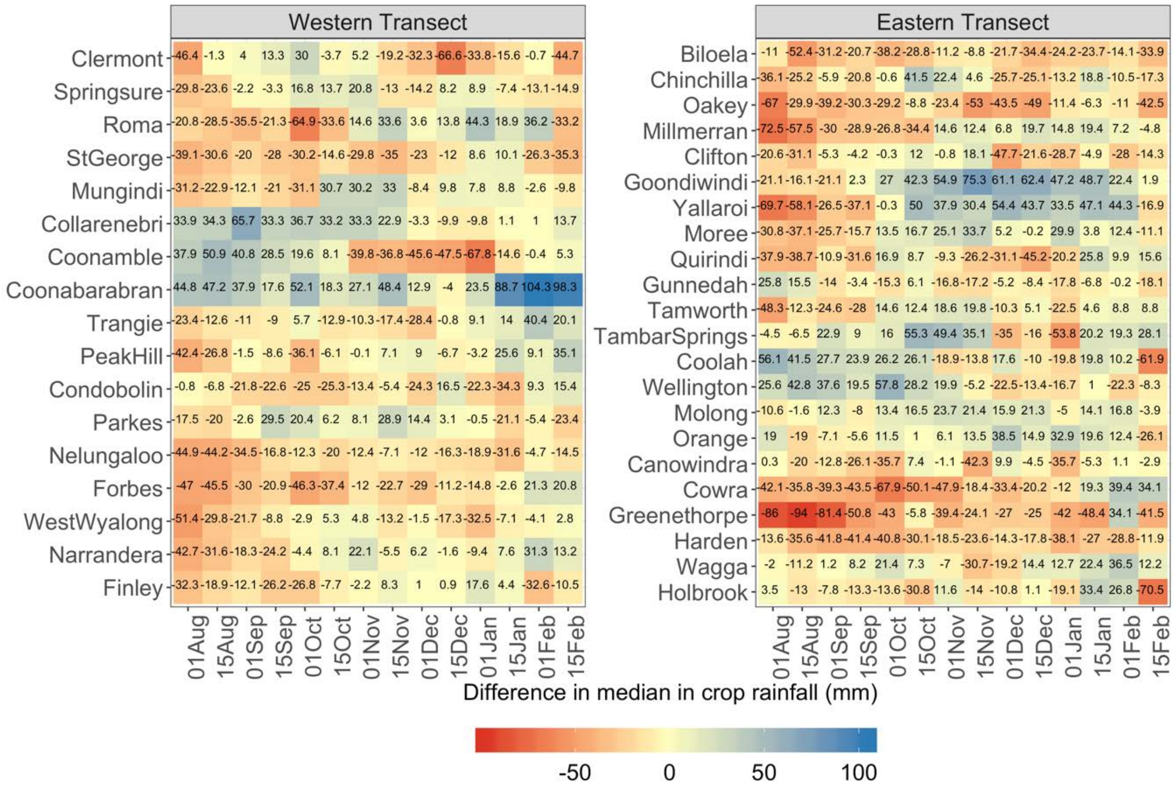

Figure 6. Difference in median in-crop rainfall for the 14 different sowing dates between the two climate periods 1958-1987 and 1988-2017, for locations in western and eastern transects. Red shading indicates a decrease in in-crop rainfall, blue shading indicates an increase in rainfall, and yellow indicates sowing dates with minimal to no difference in rainfall between normals. The values within each cell are the difference in median in in-crop rainfall (mm).

Extreme temperatures

High temperatures around flowering can significantly reduce sorghum grain yield (Lobell et al., 2015; Singh et al., 2017; 2016). The difference in the number of days with temperatures in excess of 35°C increased between the past 30-year climate normal period (1958-1987) and the more recent 30-year normal (1988-2017). The increase in days with extreme temperatures was greater for the western transect, especially for crops sown between October and November. For the eastern transect there was a general increase in the number of days with extreme temperatures for all sowing dates before December. However, a few specific sites experienced a reduction in extreme temperatures; these sites and sowing dates correspond with those that experienced an increase in rainfall and consequently an increase in median yield potential (Figure 7).

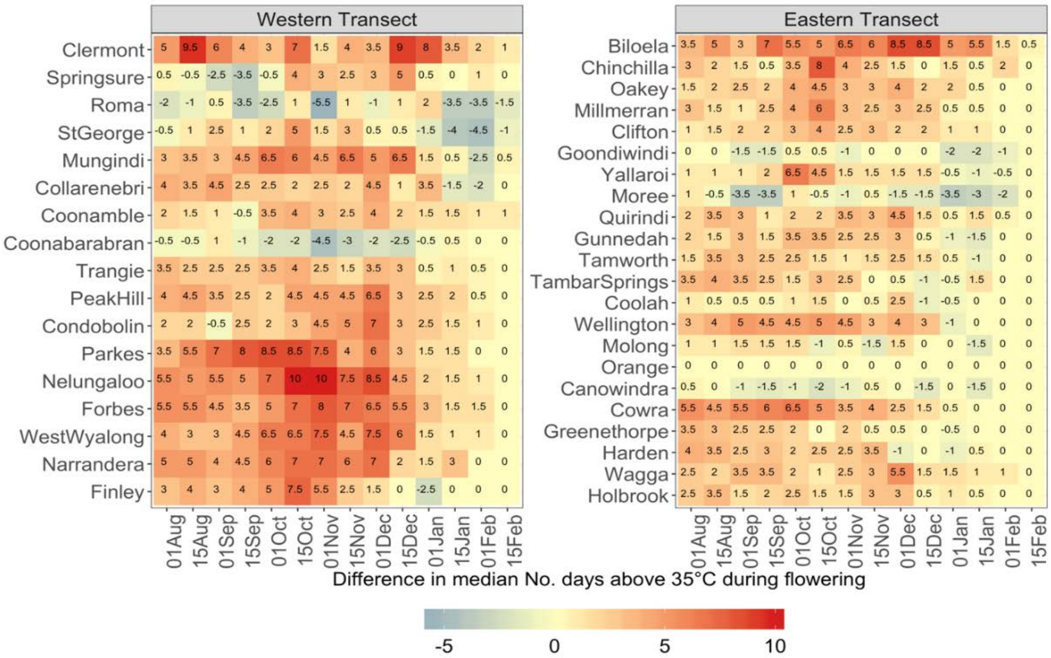

Figure 7. Difference in the median number of days above 35°C during flowering for the 14 different sowing dates between the two time periods of 1958-1987 and 1988-2017, for western and eastern transects within the northern grain zone of eastern Australia. Red indicates an increase in rainfall while blue indicates a decrease, yellow highlights those sowing dates with minimal to no difference. The values within each cell are the difference in median number of days above 35°C during flowering.

So, what does it mean and what can I do?

The climate of Australia's sorghum production area has changed, with increases in the average daily temperature, an increase in the number of days with extreme temperatures during flowering, and a decrease in in-crop rainfall for many locations. These changes have resulted in an overall reduction in crop yield potential. However, despite this decrease the yield potential has not been reduced to a point where it is no longer economical to grow sorghum. Good agronomy and the use of high soil water triggers at sowing will help maintain profitable returns under changing climates. For sites that had an increase in yield for some sowing dates, this could be traced to increased rainfall and a decrease in extreme temperatures during flowering. However, these increases were relative only to the areas historic production and not an increase above traditionally high yield regions. Thus, despite a decrease in the yield potential over the study period for many areas, this decrease was too small to cause a noticeable shift in sorghum production areas, and so NSW is not the new central Queensland for sorghum production.

Acknowledgements

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References

Arguez, A., Vose, R.S., 2011. The Definition of the Standard WMO Climate Normal: The Key to Deriving Alternative Climate Normals. Bull. Amer. Meteor. Soc. 92, 699–704. doi:10.1175/2010BAMS2955.1

CSIRO and Bureau of Meteorology 2015, Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report, CSIRO and Bureau of Meteorology, Australia.
https://www.climatechangeinaustralia.gov.au/media/ccia/2.1.6/cms_page_media/168/CCIA_2015_NRM_TechnicalReport_WEB.pdf

Lobell, D.B., Hammer, G.L., Chenu, K., Zheng, B., McLean, G., Chapman, S., 2015. The shifting influence of drought and heat stress for crops in northeast Australia. Glob Change Biol 21, 4115–4127. doi:10.1111/gcb.13022

Singh, V., Nguyen, C.T., McLean, G., Chapman, S., Zheng, B., van Oosterom, E.J., Hammer, G.L., 2017. Quantifying high temperature risks and their potential effects on sorghum production in Australia. Field Crops Research 211, 77–88. doi:10.1016/j.fcr.2017.06.012

Singh, V., Nguyen, C.T., Yang, Z., Chapman, S., van Oosterom, E.J., Hammer, G.L., 2016. Genotypic differences in effects of short episodes of high-temperature stress during reproductive development in sorghum. Crop Sci 56, 1561–1572. doi:10.2135/cropsci2015.09.0545

Whish, J.P.M., Butler, G., Castor, M., Cawthray, S., Broad, I., Carberry, P.S., Hammer, G.L., McLean, G., Routley, R., Yeates, S.J., 2005. Modelling the effects of row configuration on sorghum yield reliability in north-eastern Australia. Aust. J. Agric. Res. 56, 11–23. doi:10.1071/AR04128

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New genetics to improve wheat establishment and weed competitiveness

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Key words

wheat, breeding, genetics, dwarfing genes, coleoptile length, establishment

GRDC code

CSP00182, CSP00199, CSP00200

Take home messages

- Current Australian wheat cultivars contain dwarfing genes that reduce coleoptile length by 40%. New dwarfing genes are available that reduce plant height but don't reduce coleoptile length
- A gene increasing coleoptile length was identified and tagged with DNA markers. Breeding lines and DNA markers for new dwarfing and coleoptile length genes have been delivered to Australian breeders for efficient selection of improved crop establishment
- Deep-sowing studies in WA and NSW Managed Environment Facilities show benefit with new dwarfing and coleoptile length promoting genes in increasing emergence at sowing depths of up to 120mm but without changing plant height
- Moisture-seeking points coupled with new genetics should reliably allow seed placement and emergence from sowing depths of 100mm or greater, and/or with warmer soils
- Genetic variability exists with potential to suppress weeds through greater shoot and/or root competitiveness.

Background

In rainfed environments typical of the eastern and southern wheatbelts, crops are typically sown on the first breaking rains but sometimes moisture accumulated through summer is too deep for sowing with conventional variety × drilling systems. Key to good leaf area development for tillering, growth and weed competitiveness is good crop establishment. An ability to establish wheat crops from seed placed 80mm or deeper in the soil would be useful in situations where the subsoil is moist but the surface dry. Seeding onto moisture at depth can assist to extend the opportunities for a greater portion of the cropping program to be sown in the traditional sowing months of May and June or earlier in April following summer rain. A separate but concerning issue is the influence of increasingly warmer soil temperatures on reductions in coleoptile (the shoot that grows from the seed and allows seedling emergence through the soil) length. Earlier sowing into warmer soils will reduce coleoptile length by as much as 60% so that a variety such as Mace with a 75mm coleoptile at 15°C will likely have a 40mm coleoptile at 25°C soil temperature. Some seed dressings and pre-emergent herbicides can further reduce this coleoptile length and affect establishment.

The green revolution *Rht-B1b (syn. Rht1)* and *Rht-D1b (syn. Rht2)* dwarfing genes reduced plant heights to reduce lodging and increase grain yields and so are present in most wheat varieties worldwide. Their presence also reduces the length of the coleoptile by as much as 40%. This reduces crop emergence when sown at depths greater than 50mm, tiller number and leaf size to reduce water-use efficiency and weed competitiveness.

New dwarfing genes

A range of alternative dwarfing genes have been identified in overseas wheats with potential to reduce plant height and increase yields, while maintaining longer coleoptiles and greater early vigour. Some of these genes (e.g. *Rht8* and *Rht18*) have been used commercially overseas but have not been assessed for use here in Australia. We reduced the larger global set of alternative dwarfing genes to *Rht4, Rht5, Rht8, Rht12, Rht13* and *Rht18*, and then developed linked DNA-markers to assist with breeding of these genes in a commercial breeding program. Separately, we then bred these genes using conventional and DNA-based methods into the old, tall wheat variety Halberd for testing and disseminating to Australian wheat breeders.

Genes that promote coleoptile growth

While switching to new dwarfing genes will remove the growth inhibition on early growth, there is a need to promote coleoptile growth, particularly in the presence of conventional dwarfing genes. A gene with major effect on coleoptile length was identified in current wheat cultivars. Through a GRDC funded project, we demonstrated that the gene not only increased coleoptile length but also emergence with deep sowing in field trials conducted over three years at Yanco NSW (Figure 1). The gene was tagged with molecular markers and tested in a wide range of Australian wheat germplasm. We estimated that only 10% of recently released cultivars carry the coleoptile growth promoting gene. The markers were distributed to Australian breeding companies to assist with the selection and the expected increase of gene frequency in future cultivars. Additional genetic variation for coleoptile length and early growth exists in elite germplasm. For breeders to take full advantage of this variation, additional genes controlling this trait need to be identified and tagged with markers for efficient selection and combining growth promoting genes for even better performance.

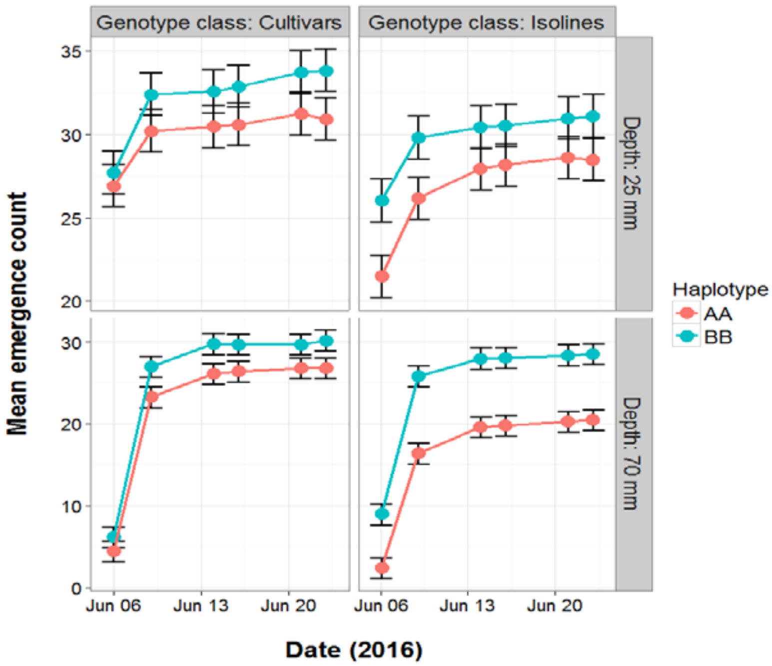

Figure 1. Emergence of wheat commercial cultivars carrying conventional dwarfing genes and tall isolines in Young background in the NSW MEF at Yanco in 2016. Sowing depth treatments were 25 mm and 70 mm depth. 12 cultivars and 12 isolines were grouped according to the presence of the coleoptile length promoting gene (BB, long coleoptiles) and the lack of the gene (AA short coleoptiles).

Preliminary sowing depth field studies

Field studies have commenced on the Halberd-based dwarfing gene lines and show that lines containing these new dwarfing genes produced coleoptiles of equivalent length to Halberd (up to 135mm in length; Figure 2) and established well when sown at 100mm depth in deep sowing experiments conducted at Mullewa and Merredin in 2016 (Figure. 3). Grain yields of lines containing the new dwarfing genes were equivalent to the yields of lines containing the commonly used *Rht-B1b* and *Rht-D1b* dwarfing genes while previous studies have shown the new dwarfing genes were linked to greater grain yields when sown deep, owing to greater plant number with improved establishment.

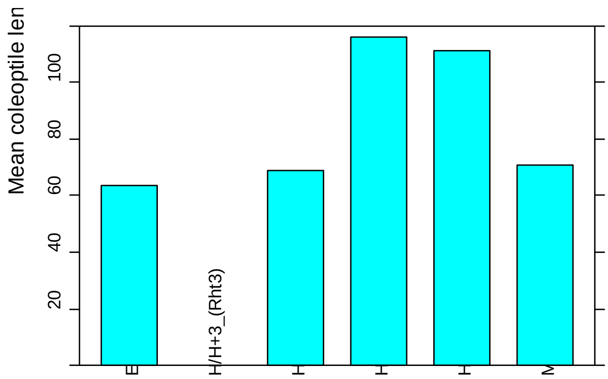

Figure 2. Coleoptile lengths of a tall wheat genotype (Halberd) and genotypes with dwarfing genes *Rht-B1b (syn. Rht1)* and *Rht8* emerging in the field in a Halberd background. Emu Rock⁽ᴾ⁾ and Mace⁽ᴾ⁾ are current commercial cultivars with *Rht-B1b* and *Rht-D1b*, respectively.

The most likely useful new dwarfing genes, *Rht13* and *Rht18*, have been bred into a range of current commercial wheats (Figures 4 and 5). Long coleoptile wheat breeding lines in Mace⁽ᴾ⁾, Scout⁽ᴾ⁾, Espada⁽ᴾ⁾, EGA Gregory⁽ᴾ⁾ and Magenta⁽ᴾ⁾ have been delivered to Australian breeders for testing and use in breeding. If there are no problems with these new dwarfing genes, we may see the first of the long coleoptile wheat varieties in 3-4 years in NVT testing!

Agronomic opportunities

Although there is real promise in the new genetics, there is significant opportunity in coupling new genetics with new existing seeding technologies. Deep sowing is an issue overseas and in the eastern Australian states. The availability of moisture-seeking points commonly used elsewhere should allow the reliable placement of seed at depths of 100mm or greater. These points produce a slot deep into the soil at the base of which a seed is sown at 10-50mm depth. That said, further research is required aimed at tools and methods assessing across different moisture-seeking points to optimise seed placement at depth across a wide range of soil types.

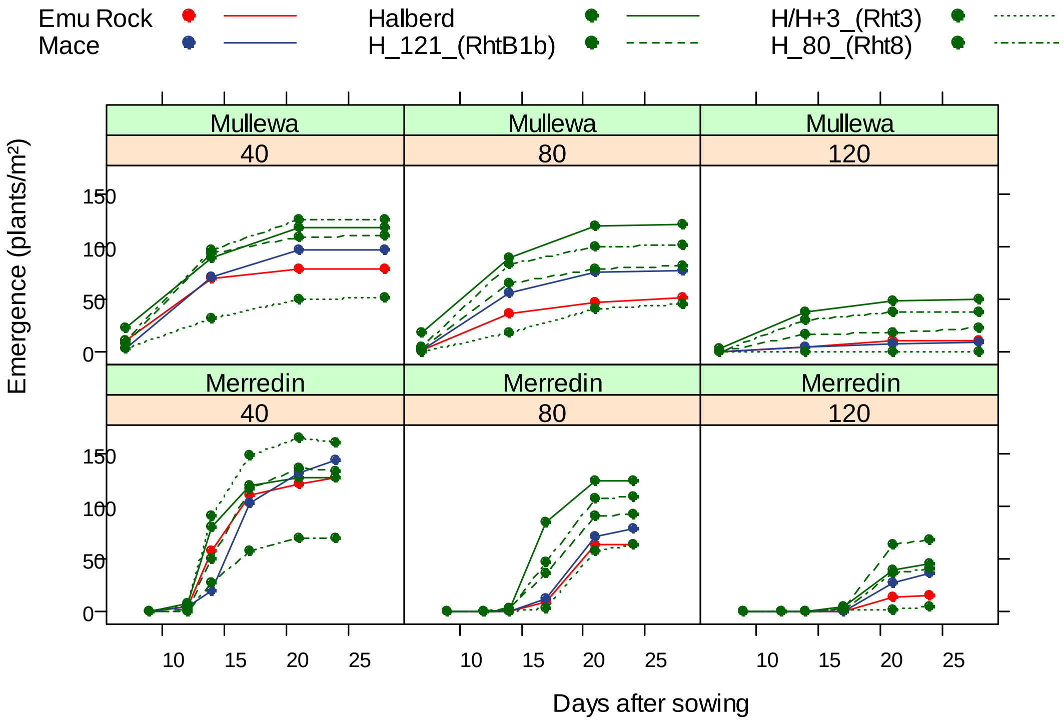

Figure 3. Patterns of emergence of wheat genotypes with different dwarfing genes sown at target depths of 40, 80, or 120 mm at Mullewa and Merredin in 2016 (after French *et al.* 2017).

Weed competitiveness

Weeds cost Australian grain growers an estimated $4B annually through lost production, reductions in crop quality, and herbicide use. These costs are unlikely to reduce with pressure on new actives in the widespread development of herbicide resistance in multiple weed species. Observed differences across cereal species and wheat varietal differences in crop competitiveness with weeds, provides impetus to use breeding and genetic improvement to aid in-crop weed control. In wheat, comparisons across a historic 100-year set of varieties highlighted that older varieties were more competitive with weeds. Presumably, this reflects selection for improved performance in the absence of in-crop herbicides. Overseas studies have demonstrated a reduction in herbicide use of up to 50% when using weed-competitive wheats, while a broader benefit is in integrating competitive varieties with cultural management (e.g. weed seed harvest and tillage) to slow herbicide resistance and reduce herbicide use.

Competitiveness can be thought of as the partial to complete suppression of competing weeds to increase crop yield, or the ability of a variety to tolerate a competitor to maintain higher yields. Selection for greater tolerance is a breeding strategy for many crop insects and diseases but is of less value in weed management as low numbers of weed survivors replenish the seed bank for the next season. In turn, breeding of competitive crops has focussed on selection of genotypes that can better access light, water and nutrients to suppress the growth of weeds. Greater early vigour, as rapid leaf area development and biomass at stem elongation and altered root architecture are mechanisms that contribute to the ability to out compete weeds. Root exudates used in plant defence (allelopathy) may also slow the growth of neighbouring competitors.

In cereals, greater leaf size and rapid early leaf area development are associated with larger seed embryos, higher leaf area, and new dwarfing genes for reducing stem height. Unfortunately, commercial wheat varieties selected for increased yield potential often exhibit poor early growth. A global survey identified 30 wide-leafed, wheat donors which were subsequently used in a CSIRO long-term breeding activity to accumulate favourable genes to increase early vigour. High vigour lines derived from this program have been used to develop wheats with capacity to suppress the growth of ryegrass by up to 50% (Zerner et al. 2016). Field comparisons between current semi-dwarf wheat varieties and weed-competitive wheat breeding lines indicate wheat yield loss and weed suppression is greater in the weed-competitive lines (Figure 4).

Breeding companies are limited in their ability to develop and deliver new traits. The identification of new opportunities that will deliver greater grower profitability together with development of a clear value proposition will allow for pre-breeders to identify those traits and their underlying genetics and methods in selection for uptake by commercial breeders. In the case of weed competitiveness, the genes for weed suppression have come from outside existing breeding programs and include old Australian varieties and overseas landraces. Parental germplasm has been developed over many years and intercrossed into modern Australian varieties. Together with high-throughput selection methods, these populations have been delivered to Australian breeders for use in their commercial breeding efforts toward new weed competitive wheat varieties.

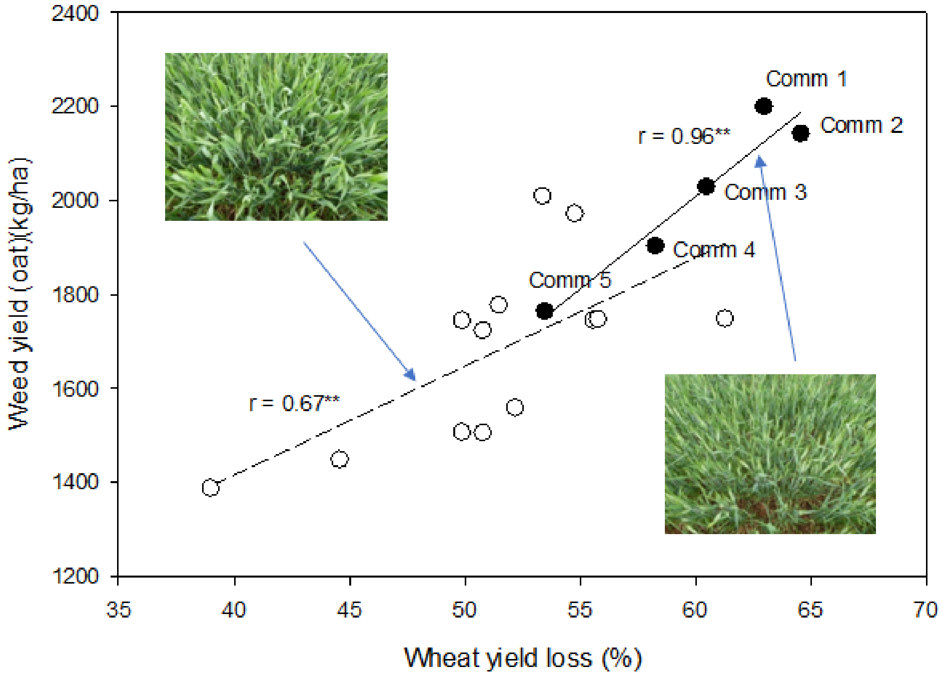

Figure 4. Relationship for yield loss in wheat and growth (as yield) of a weed mimic (oats) for breeding lines (○) and commercial wheat varieties (●) in field plots.

Summary

Wheat breeders now have the new dwarfing genes to breed longer coleoptile wheat varieties. Genes that increase coleoptile length have also been identified and tagged with markers. These genes are expected to play an important role in improving emergence from depth in the presence of conventional dwarfing genes. Matching new genetics with appropriate agronomy and technologies should ensure the emergence and establishment of deep-sown wheats, particularly when sown early to make use of summer rains sitting deep in the soil profile or to increase sowing opportunities in the traditional months of May and June.

References

French B, Zaicou-Kunesch C, Rebetzke G (2017) Alternative dwarfing genes improve emergence from deep sowing. GRDC Updates Perth

Zerner RK, Gill GS, Rebetzke GJ (2016) Stability of wheat cultivars in weed competitive ability in differing environments in southern Australia. *Crop and Pasture Science* **67**, 695-702

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Figure 5. Wheat variety Mace⟨PBR⟩ (left) side-by-side with long coleoptile, Mace⟨PBR⟩ containing the *Rht18* dwarfing gene (right) at Condobolin in 2017.

Figure 6. Wheat variety EGA Gregory⟨PBR⟩ (left) side-by-side with long coleoptile, EGA Gregory⟨PBR⟩ containing the *Rht18* dwarfing gene (right) at Condobolin in 2017.

Cover crops can boost soil water and protect the soil for higher crop yields

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Key words

cover crops, millet, ground cover, soil water storage, fallow management, stubble, evaporation, infiltration, plant available water

GRDC code

DAQ00211

Take home messages

- Cover crops can increase fallow water storage, and improve crop performance and returns in northern farming systems
- In each experiment, a cover crop treatment provided the highest plant available soil water by the end of the fallow
- The best cover crop treatment depended on the length of the fallow. A later spray-out, with more resilient cover, was best in the longer fallow. However, delaying spray-out too long had a dramatic effect on water storage
- Cover crop saved 2-3 fallow herbicide sprays and dramatically improved establishment at one of the sites
- Yields and returns were increased by the best cover crop treatment at each trial, but yield effects appear to be in excess of those expected from the increased soil water storage
- Biology effects must be considered carefully; white French millet cover crops in the northern region have previously been shown to dramatically increase mycorrhizal colonisation of wheat (good), increase free-living nematodes (good), increase cellulase activity and bacterial abundance from additional fresh crop residues (good), but also increase root-lesion nematode populations (bad).

Cover crops in the northern region

Cover crops are not new. They have been used (mostly) by organic and low-input growers to protect the soil from erosion in low stubble situations, return biomass that helps maintain soil organic matter and biological activity, and to provide additional nitrogen when legumes are used.

However, growing cover crops uses water, and storing Plant Available Water (PAW) is 'king' in northern farming systems; only 20-40% of the northern region's rainfall is typically transpired by dryland crops, up to 60% of rainfall is lost to evaporation, and a further 5-20% is lost in runoff and deep drainage. Every 10 mm of extra stored soil water available to crops could increase dryland grain yields by up to 150 kg/ha, with corresponding benefits to dryland cotton growers as well. So, growing crops that do not produce grain or fibre is understandably considered 'wasteful' of both rainfall and irrigation water.

Yet, research is now supporting growers' experience that cover crops can provide many of their benefits with little or no net loss of soil water at the end of the fallow period. GRDC's Eastern Farming Systems project and Northern Growers Alliance (NGA) trials have both shown that cover crops and increased stubble loads can reduce evaporation, increase infiltration and provide net gains in plant available water over traditional fallow periods. This suggests cover crops may be a key part of improved farming systems; providing increased productivity, profitability and sustainability.

The science of stubble and evaporation

Retained stubble provides ground cover that protects the soil from rainfall impacts and so improves infiltration to store more water in the soil. Conventional wisdom is that increased stubble loads can slow down the initial rate of evaporation, but that these gains are short-lived and lost from accumulated evaporation after several weeks. However, further rain within this period and the manipulation of stubble to concentrate stubble loads in specific areas, provide an opportunity to reduce total evaporation and to accumulate more plant available water.

In southern Queensland and northern NSW, cover crops are used to overcome a lack of stubble and protect the soil following low residue crops (e.g. chickpea, cotton) or following skip-row sorghum with uneven stubble and exposed soil in the 'skips'.

Growers typically plant white French millet or sorghum and spray them out within ~60 days to allow recharge in what are normally long fallows across the summer to the next winter crop. Allowing these 'cover crops' to grow through to maturity led to significant soil water deficits and yield losses in subsequent winter crops. However, the Eastern Farming Systems project showed only small deficits (and even water gains) accrued to the subsequent crops when millets were sprayed out after 6 weeks, with average grain yield increases of 0.36 t/ha. Furthermore, the Northern Growers Alliance showed that the addition of extra stubble (from 5-40 t/ha) after winter crop harvest appeared to reduce evaporation, with initial studies showing between 19 mm and 87 mm increases in plant available water. These gains will be valuable if validated in further research and captured in commercial practice.

Our current project is monitoring sites intensively to quantify the impact of different stubble loads on the accumulation of rainfall, the amount of water required to grow cover crops with sufficient stubble loads, the net water gains/losses for the following crops and the impacts on their growth and yield. This paper reports on the first two sites in southern Queensland, which will be used in simulation/modelling later in the project to assess the wider potential and economic impacts of cover crops in both grain and cotton production systems.

Experiment 1 – Yelarbon (pivot-irrigated cotton, short fallowed to pivot irrigated cotton)

The Yelarbon experiment was on a pivot-irrigated paddock that grew cotton in 2016/17. The crop was picked and root cut in May, before offset discs were used on 12 June 2017 to pupae-bust and to level wheel tracks of the pivot irrigator. Nine cover treatments (Table 1) with five replicates were planted on the same day using barley (100 plants/m^2), barley and vetch mixtures (30 plants/m^2 each) and tillage radish (30 plants/m^2). Rain that night aided establishment, and the surrounding paddock was planted two weeks later to wheat for stubble cover.

Three planned termination times matched key growth stages of the main cereal treatments: Early-termination at first node (Z31) when the crop begins stem development; Mid-termination at flag leaf emergence (Z41) when the reproductive phase begins; and Late-termination at anthesis (Z65) for peak biomass production. Biomass of the cover crop treatments at their relevant termination times ranged from 1166 kg dry matter (DM)/ha (early) to 8175 kg DM/ha when the crop was grown through to grain harvest (Table 1).

The subsequent cotton crop was planted on 15 November 2017 and irrigated on a schedule determined by the surrounding wheat crop that was harvested for grain. We included a 'grain harvest' treatment in our experimental plots to align with the farmer's practice. Above ground biomass was also monitored across the growth of the cover crops until termination and through the subsequent fallow. Establishment was counted in all plots and hand cuts used to estimate cotton yields.

Table 1. Cover treatments applied at the Yelarbon site prior to planting cotton

Treatment	Cover crop	Termination time	Biomass (kg/ha)
1.	Control (Bare)		
2.	Cereal	Early-sprayout	1166
3.	Cereal	Mid-sprayout	4200
4.	Cereal	Late-sprayout	5104
5.	Cereal	Mid-sprayout + Roll	4200
6.	Cereal	Grain harvest	8175
7.	Cereal + legume	Mid-sprayout	4928
8.	Cereal + legume	Late-sprayout	4149
9.	Tillage radish	Mid-sprayout	4692

Soil water

Soil water was estimated using soil cores to measure gravimetric soil water at key times across the fallow and the subsequent cotton, along with regular neutron moisture meters (NMM) and EM38 readings in each plot. These NMM and EM38 readings and the percentage ground cover were recorded every two-to-four weeks while the cover crops were growing, and every four weeks once all cover crops were terminated, and until canopy closure of the following cotton was achieved. Final EM38 and NMM readings were recorded at cotton defoliation.

The water cost of growing the barley cover crops, relative to the control treatment in the early stages of the fallow was ~40 mm for the early-termination, ~70 mm for the mid-termination and ~120 mm for the late-termination (Figure 1). However, by the end of the fallow, and a subsequent 170 mm of rainfall/irrigation in 8 events from mid-termination to cotton plant, the mid-termination treatment caught up to the control, and the early-termination had accumulated an additional 14 mm of water. Not surprisingly, this early-termination proved to be the best cover crop treatment on the short fallow. The crop that continued to harvest was ~145 mm behind by the end of the fallow. This treatment mirrored the wider paddock and so set the following pivot irrigation schedule.

Crop performance

The irrigation schedule matched to the harvested crop provided more than adequate water across the cover crop treatments and yields for all cover crop treatments were similar. However, the Control with limited ground cover was the poorest performer, with ~3 bales/ha lower yield, lower infiltration in early growth stages and less extraction of water late in the crop.

The nominal costs to plant the cover crops ($50/ha) and to spray them out ($20/ha) were almost matched by the savings from three less fallow weed sprays ($60); so the measured cotton yield responses were very profitable. For grain growers, the extra 14 mm stored moisture from the early-termination cover crop would typically produce ~200 kg/ha grain in wheat at a water use efficiency of 15 kg grain/mm water, which is worth ~$50/ha (at $270/t) and would produce an overall return of $40/ha. Any further possible benefits from cover crops, which appear to have occurred in the cotton crop, have not been included.

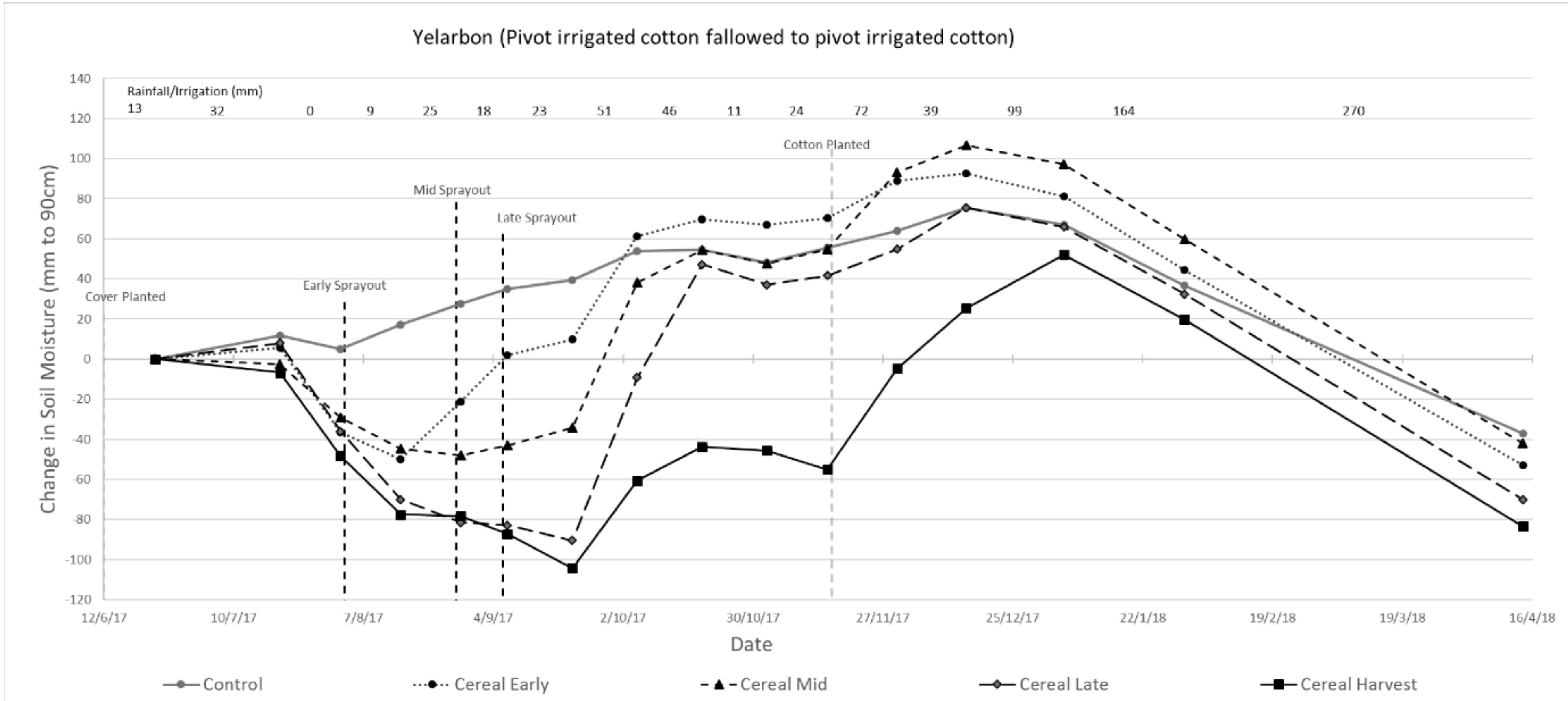

Figure 1. Changes in soil water (mm to 90 cm) from planting of key cover crop treatments until defoliation of the subsequent cotton crop at Yelarbon

Table 2. Net change in water storage over the life of the fallow (relative to the Control) and final cotton yield for each cover crop treatment at Yelarbon.

Treatment	Cover crop	Terminated	Water gain (cf control)	Cotton yield (bales/ha)
1.	Control (bare) Starting water ~100mm PAW		56 mm (fallow gain)	9.3
2.	Cereal	Early	+14 mm	12.9
3.	Cereal	Mid	-1 mm	12.7
4.	Cereal	Late	-14 mm	11.9
5.	Cereal	Mid + Roll	-2 mm	12.6
6.	Cereal	Harvest	-111 mm	14.1
7.	Cereal + legume	Mid	-16 mm	11.9
8.	Cereal + legume	Late	-7 mm	13.9
9.	Tillage radish	Mid	-40 mm	14.4

Experiment 2 – Bungunya (Skip-row sorghum, long- fallowed to dryland wheat)

The Bungunya experiment was in a long-fallow paddock following skip-row sorghum harvested in early February 2017. The paddock had deep phosphorus applied in August 2017 and was 'Kelly-chained' in September 2017 to level the paddock, which left it with little cover until the planned wheat crop. Cover crops were planted into ~120 mm of plant available soil water on 11 October. The subsequent wheat crop was planted on 1 May 2018, with hand cuts for yield done on 12 October and mechanical harvesting on 26 October. Soil water, cover crop and stubble biomass, ground cover, wheat establishment and yields were measured in the same way as the experiment at Yelarbon.

Table 3. Cover treatments applied at the Bungunya site prior to planting wheat

Treatment	Cover crop	Termination time	Biomass (kg/ha)
1.	Control (Bare)		
2.	Millet (White French)	Early-sprayout	1533
3.	Millet (White French)	Mid-sprayout	2327
4.	Millet (White French)	Late-sprayout	4365
5.	Millet (White French)	Mid-sprayout + Roll	2476
6.	Millet (White French)	Late-sprayout + Roll	4737
7.	Sorghum	Mid-sprayout	2481
8.	Lab Lab	Mid-sprayout	1238
9.	Multi-species (millet, lab lab, radish)	Mid-sprayout	1214

Soil water

The water cost of growing the millet cover crops, relative to the Control treatment in the early stages of the fallow was ~50mm for the early-termination, ~40 mm for the mid-termination and ~60 mm for the late-termination (Figure 2). The lab lab mid-termination treatment also cost ~60 mm to grow, relative to the Control treatment. These figures reflect rainfall and different rates of infiltration between soil water measurements:

- Plant to mid-termination, 65 mm in 3 events (12/10/17 to 22/11/17)
- Mid-termination to plant, 205 mm in 11 events (22/11/17 to 1/5/18)

- Follow crop plant to maturity 41mm in 3 events (1/5/18 to 10/10/18)
- Follow crop maturity to soil sample 72mm in 7 events (10/10/18 to 5/11/18)

By early March, with a subsequent 175 mm of rain in ten falls after the mid-termination, the millet treatments had all recovered to have effectively the same soil water as the Control, except where the late-terminated millet was rolled; it had gained ~20 mm more water than the other treatments.

When the subsequent wheat crop was planted, the mid-terminated millet had ~14 mm more soil water than the Control treatment, the late millet ~19 mm more, and the late millet that was also rolled had ~36mm more soil water (Table 4). Interestingly, water extraction by the wheat crop was greater from all of the millet cover crop plots than the Control, which had lower yields; perhaps due to, or resulting in less root development.

Crop performance

All cover crop treatments increased the yield of the final wheat crop (Table 4) and saved two fallow weed sprays (~$40/ha). However, the biggest yield increases were from the cereal cover crops, especially the late-terminated millet and the sorghum.

The water differences at planting (end of the fallow) may explain some of the yield difference. However, the establishment of the wheat crop was dramatically better where cover crops were used, more so where cereals were used but also for lab lab. The expected yield increases from the higher fallow water storage alone would typically be ~200 kg grain in wheat (WUE 15 kg grain/mm water) for the mid-terminated millet (worth ~$50/ha), ~280 kg grain for the late millet (worth $75/ha) and ~540 kg grain for the late +rolled millet (worth $150/ha). These gains would represent net returns of $20/ha, $45/ha and $120/ha respectively. However, the measured yield gains for these treatments were 950 kg/ha, 1461 kg/ha and 1129 kg/ha respectively, representing increase returns of between $250 and $380 /ha.

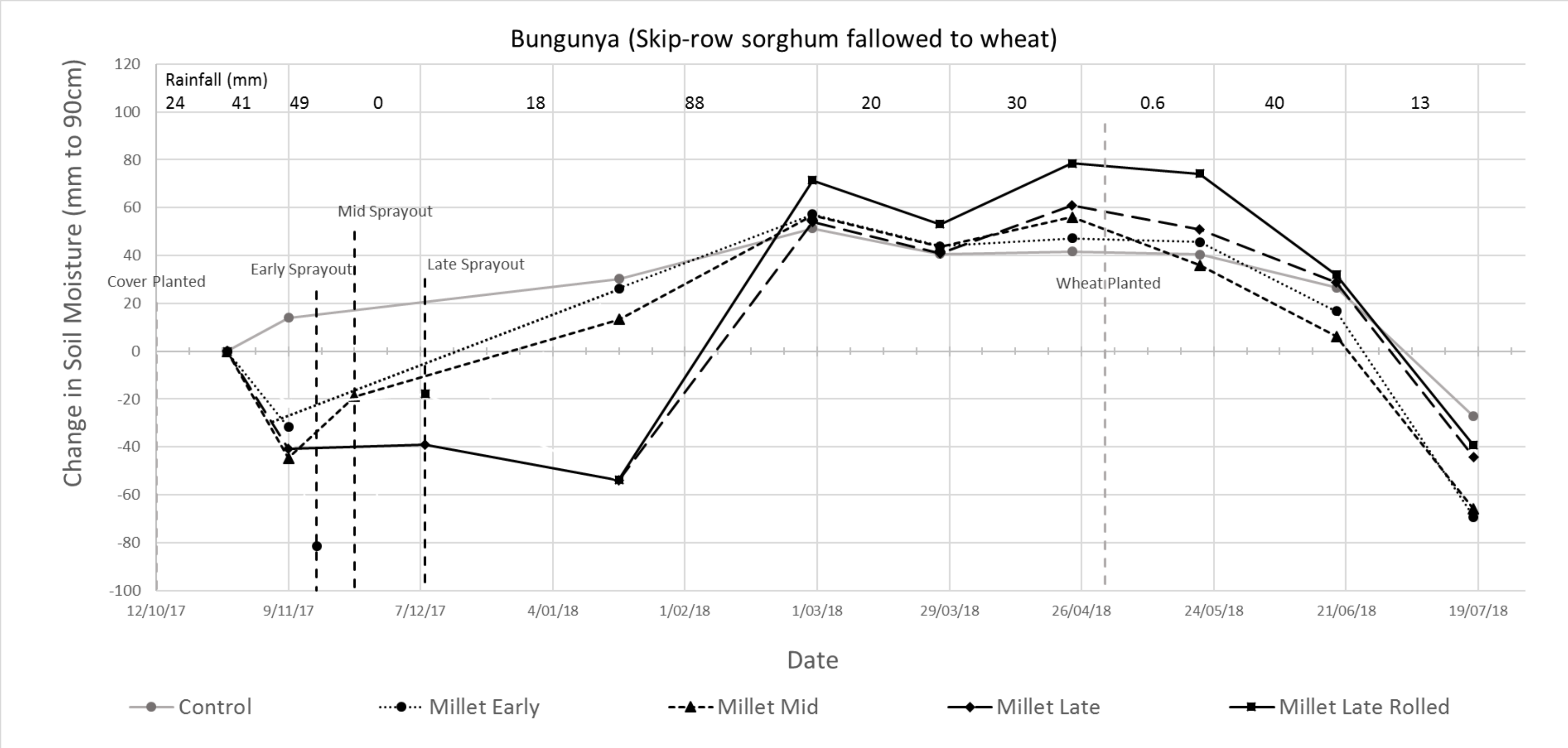

Figure 2. Changes in soil water (mm to 90 cm) from planting of the millet cover crop treatments sprayed out at different crop growth stages until harvest of the later wheat crop at Bungunya

Table 4. Net change in water storage over the life of the fallow (relative to the Control) and final wheat yield for each cover crop treatment at Bungunya.

Treatment	**Cover crop**	**Terminated**	**Water gain (cf control)**	**Wheat yield (kg/ha)**
1.	Control (bare) Starting water ~120mm PAW		42mm (fallow gain)	1436 [f]
2.	Millet (White French)	Early	+5 mm	2223 [cd]
3.	Millet (White French)	Mid	+14 mm	2386 [bc]
4.	Millet (White French)	Late	+19 mm	2897 [a]
5.	Millet (White French)	Mid + Roll	+17 mm	2359 [bc]
6.	Millet (White French)	Late + Roll	+36 mm	2565 [b]
7.	Sorghum	Mid	+17 mm	2634 [ab]
8.	Lab Lab	Mid	-4 mm	1795 [e]
9.	Multi-species (millet, lab lab, radish)	Mid	+21 mm	1954 [de]

Potential biological impacts

These two experiments focused on soil water accumulation. Biological analysis was not undertaken, but some exploratory analyses will be included for selected treatments in future trials. However, past biological assessments on the Eastern Farming Systems project sites around Goondiwindi highlighted a range of biological effects following white French millet cover crops.

Mycorrhizal colonisation of roots in six-week-old wheat from 1.8% in the long-fallow following skip-row sorghum to 8.3% following an early terminated millet cover crop in the fallow (Seymour *et al.* 2006); crop growth was much stronger following the cover crop. Other positive biological effects included increases in free-living nematodes and cellulase activity that indicate a more active biological system with a greater food source from more residues; and increased Nematode Channel Ratios, which indicates greater bacterial activity from more disturbance and addition of higher quality residues (Table 5). Unfortunately, the white French millet cover crop also boosted root-lesion nematodes (*Pratylenchus* sp.), and so cover crop species must be selected carefully where root-lesion nematodes are a problem.

Table 5. Selected biological effects at wheat planting after a 15 month fallow from skip-row sorghum +/- a white French millet cover crop with different termination dates near Goondiwindi (Seymour *et al.* 2006)

District	**Treatment**	***Pratylenchus* sp/g soil**	**Free living nematodes/g soil**	**Nematode channel ration (0= fungal; 1= bacterial)**	**Cellulase assay**
Lundavra	Fallow	0.64	0.58	0.39	0.21
	Short-term millet	1.31	2.76	0.39	0.59
	Mature millet	2.51	7.33	0.57	0.89
North Star	Fallow	0.92	0.65	0.52	0.03
	Short-term millet	0.92	7.41	0.79	0.23
	Mature millet	1.45	5.25	0.87	0.11
LSD	(P=0.05)	0.51	2.96	0.19	0.31

Conclusions

The project results show that cover crops can indeed help increase net water storage across fallows that have limited ground cover. Importantly, these results were achieved in drier than normal seasons. For example, the Bungunya site with millet cover crops had a wet spring that allowed a well grown cover crop to develop, but was then followed by well below average rainfall through the fallow, with a few good storms in February/March. How often these soil water results will occur across different seasons will be explored across the rest of the project with further experiments and simulation modelling.

However, more dramatic are the early yield results for the subsequent cotton and wheat crops at each site. These yield responses are very large and represent big improvements in returns; far beyond what could be expected from the increases in net soil water storage across the fallows. Wheat establishment dramatically improved in the Bungunya experiment, and there was greater water extraction (especially at depth) in the Yelarbon experiment. How much of the responses can be attributed to these factors, how often such results might occur, and the contributions of other factors to these gains remains to be explored.

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References

Seymour NP, Bell MJ, Price LJ, Stirling GR and Stirling AM (2006) Improving soil biology through using millet (*Panicum mileaceum*) as a short-term fallow cover crop. 4th Australasian Soilborne Diseases Symposium. Queenstown New Zealand. 3-6 September 2006

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Can we refine planting dates further?

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Key words

Planting date, frost risk, heat risk, optimum flowering window, elevation

GRDC code

AMPS00010

Take home messages

- Of all the agronomic "levers" available to growers planting date still offers one of the greatest abilities to increase yield potential.
- There are drastic changes in frost risk with only small changes in elevation (20-50 m), which presents significant opportunity to push planting dates forward without necessarily increasing frost risk.
- Lower points in the landscape/paddock have more frost events with greater duration compared to higher elevations. Therefore there is slower accumulation of growing degree days at these lower points in the landscape, consequently slowing the development of the crop.
- There is little variation in maximum temperature across elevations. Therefore in lower parts of the landscape, where the frost risk persists longer into the season, the heat stress will start at the same time as higher elevations. This narrows the window for optimum conditions for flowering crops.

Introduction

Major management "levers" that can be manipulated to achieve yield potentials include planting date, planting configuration (row spacing and seeding rate), variety choice, disease and weed control, nitrogen, phosphorus and other nutrition. Of these "levers" planting date can have the greatest impact achieving yield potential and is one of the few management tools that can be changed with negligible additional costs to the grower. The degree that planting date will determine grain yield potential will be greatest in dry and hot springs and least in wet and mild springs.

Planting date determines when the plant will reach anthesis. Pushing sowing dates earlier increases yield potential through increased biomass accumulation and by extending the length of grain filling period under cooler spring temperatures. However, earlier planting dates also increase the risk of incurring a frost during flowering. Sowing later to minimise frost risk then pushes crops to grain fill under hotter spring conditions leading to lower yield potentials. The key question is are we losing yield with current grower sowing dates and what other tools are available to manage our sowing dates as early as possible without taking on board unacceptable frost risk. Growers generally take a conservative approach to planting date as the fear of frost damage influences their decisions to a greater extent than the often intangible yield loss from heat stress during grain fill.

Currently growers and agronomists rely heavily on previous experience, local weather station data, sowing guides and predictive models such as Climate or APSIM to determine planting dates. The problem for growers and agronomists is that typically the local weather stations are located some distance from paddocks or farms which then requires a degree of interpellation. Models are also based on these weather stations as well, which means growers can only use results as a guide. In relatively flat areas like Walgett the individual farm variation from the weather station may be very small. For other locations like the Liverpool Plains where there is a large variation in elevations there is likely to be large differences across farms in their temperature regime as compared to the Gunnedah or Quirindi weather stations.

This project aims to reduce some of the interpellation required by growers and agronomists by looking at the impact that elevation has on frost risk and subsequently planting dates across different elevations. However, the project hasn't taken into account other factors that will influence frost risk or cold air drainage such as aspect, drainage, tree lines and the point in the landscape. The data produced from this project could be used in models to enable them to better predict frost risk and planting dates across the landscape rather than localised near a weather station.

What has been done?

In 2014, 2015 and 2016 two paddocks containing significant elevation differences (20 – 45m) were selected, one near Gurley and one on the Liverpool Plains. In each paddock a site was selected at the top of the slope and a site was selected at the bottom of the slope. Tiny Tags were installed along with rain gauges at both sites in each paddock to record temperature (every 15 minutes) and rainfall. Six wheat varieties including LPB Dart⌽, LPB Spitfire⌽, Suntop⌽, LPB Lancer⌽, EGA Gregory⌽ and EGA Eaglehawk⌽ were planted on three planting dates (Approximately Last week of April, Mid May and Early June for all trials) at both sites. Regular phenology measurements were taken to ascertain development difference both between varieties but also between top and bottom slopes. A summary of the site planting dates and elevation differences is given in Table 1.

Table 1. Details of planting dates and elevation differences at each site between 2014 and 2016

	Premer 2014	**Gurley 2014**	**Spring Ridge 2015**	**Gurley 2015**	**Premer 2016**	**Gurley 2016**
Planting Dates	30th April 20th May 13th June	26th April 16th May 11th June	30th April 19th May 11th June	26th April 15th May 8th June	29th April 18th May 13th June	30th April 17th May 10th June
Elevation Difference	401-377 (24 m)	271-302 (32 m)	354-309 (45 m)	306-263 (43 m)	384-404 (20 m)	309-274 (35 m)

Trial results

Estimations of starting plant available water (PAW) indicated that although profiles were similar between top and bottom slope at all sites the bottom slope generally had slightly higher starting PAW between 2 and 20 mm more than the top of the slope. In 2015 and 2016 the starting PAW was approximately 70 to 90% full at the Liverpool Plains and Gurley sites, however, in 2014 starting PAW was closer to 50% full at both locations (Table 2). Similar to starting PAW the measured available soil N values were generally slightly higher at the bottom slope sites compared to the top of slope sites containing an additional 2-17 kg N/ha available at the start of the season (Table 2).

The elevation differences at both sites resulted in significant variation in temperature over the season. Average minimum temperatures across all three years were 2.4 and 2.9°C lower at the bottom slope compared to the top slope at the Liverpool Plains and Gurley, respectively, whereas average maximum temperatures were similar for both top and bottom slopes (Table 2). The differences in average minimum temperatures was exemplified by the differences in frost events (<0°C) with bottom slope at the Liverpool Plains and Gurley. At Spring Ridge and Premer in 2014, 2015 and 2016 the bottom slope experienced an additional 27, 35 and 28 frost events, respectively, compared to the top slope (Table 2). At Gurley in 2014, 2015 and 2016 the bottom slope experienced an additional 31, 29 and 36 frost events, respectively, compared to the top slope (Table 2). There were not only more frosts at the bottom slope sites but frosts had a greater duration. On average across years the time that temperatures were at or below 0°C at the top slope was only 36 and 7% of that measured for the bottom slope sites on the Liverpool Plains and Gurley, respectively (Table 2). Length of the frost event can be a major determining factor of damage. On average across the three years the length of frost events at the top slope sites were 3.3 and 2.5 hours for the Liverpool Plains and Gurley, respectively. This is compared to the bottom slope sites on the Liverpool Plains and Gurley where frost events typically lasted for 4.3 and 4.6 hours, respectively. Lower average minimum temperatures and greater number of frost events both contributed to the slower accumulation of thermal time throughout the season at the bottom slope compared to the top slope. At both locations the difference in accumulated thermal time (Growing Degree Days – GDD) was in excess of 150 GDD higher at the top slope sites (Table 2).

Table 2. Soil and temperature differences between top and bottom slope at all sites from 2014 to 2016

Site	Slope	Starting PAW	Soil N (0-1.2m)	Average Min	Average Max	Frost events (<0°C)	Cum. Hours <0°C	Season GDD
Premer 2014	**Top**	139	110	5.1	24.6	31	97	1963
	Bottom	158	122	2.5	24.8	58	226	1655
Gurley 2014	**Top**	90	154	7.1	30.7	7	21	2230
	Bottom	108	145	4.4	30.3	38	184	2038
Spring Ridge 2015	**Top**	185	175	5.4	22.6	16	32	1998
	Bottom	200	192	2.6	23.1	51	243	1752
Gurley 2015	**Top**	144	104	6.4	25.2	7	17	2186
	Bottom	146	118	2.9	24.8	36	176	2008
Premer 2016	**Top**	225	125	4.9	22.8	31	132	1869
	Bottom	230	128	3.1	22.9	59	253	1655
Gurley 2016	**Top**	115	138	6.8	27.9	1	0.45	2138
	Bottom	126	142	4.3	28.0	37	143	1967

The variation of minimum temperature and ultimately GDD had significant impact on crop maturity. Despite being planted on the same day at the top and bottom slope sites the varieties, did not reach 50% flowering on the same day. An example of how visual this difference was is given in figure 1. The bottom slope sites were on average across the six varieties 13, 9 and 7 days longer than the top slope to reach flowering on the late April, mid May and early June planting dates, respectively for the Liverpool plains (Table 3). Similarly, for Gurley the differences in time taken to reach flowering were 9, 8 and 6 days longer at the bottom slope sites than the top slope for the late April, mid May and early June planting dates, respectively (Table 3). The Liverpool Plains trials were on average 17 days later to reach flowering compared to the Gurley trials across the three years (Table 3).

Table 3. Average days to flower for LPB Dart$^{\phi}$, LPB Spitfire$^{\phi}$, Suntop$^{\phi}$, EGA Gregory$^{\phi}$, LPB Lancer$^{\phi}$ and EGA Eaglehawk$^{\phi}$ plant across three planting dates at the top and bottom slope sites at the Liverpool Plains and Gurley.

Site	Slope	Late April	Mid May	Early June
Premer 2014	**Top**	131	126	116
	Bottom	147	138	127
Gurley 2014	**Top**	94	114	102
	Bottom	106	123	108
Spring Rdg 2015	**Top**	130	124	117
	Bottom	144	133	124
Gurley 2015	**Top**	118	109	99
	Bottom	126	116	106
Premer 2016	**Top**	141	132	121
	Bottom	149	135	126
Gurley 2016	**Top**	123	119	110
	Bottom	130	126	116

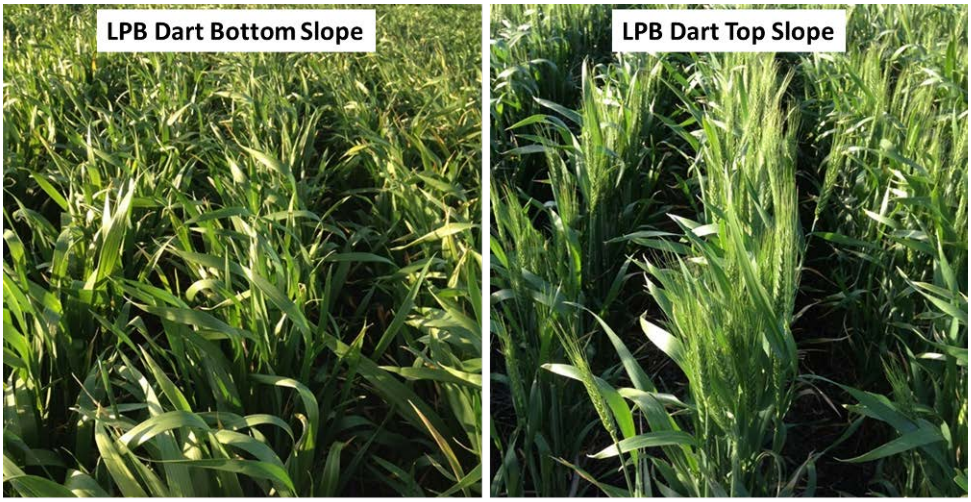

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Figure 1. A visual representation of how different maturity was between top and bottom slope at Spring Ridge in 2015.

Both the Liverpool Plains and Gurley experienced hot and dry springs in 2014 and 2015 and in these seasons the real benefit of early planting was realised. For example on the Liverpool Plains at the top slope site delaying planting from late April to early June resulted in a 2.24 and 1.04 t/ha loss in grain yield when averaged across six varieties in 2014 and 2015, respectively (Table 4). Assuming a wheat price of $250/t this is equivalent to $560/ha and $260/ha increase in net returns, respectively. Despite very favourable spring conditions on the Liverpool Plains in 2016 there was still a 1.34 t/ha yield penalty for delaying planting dates from late April to early June at the top of the slope. Again assuming a wheat price of $250/t the late April planting date allowed an additional $425/ha and $1155/ha net return to be realised, compared to the mid May and early June planting dates, respectively at the top of the slope over three years (Table 4). Frost damage did occur at the bottom slope sites on the Liverpool plains in all three years, particularly in LPB Dartⓟ and LPB Spitfireⓟ. For example LPB Dartⓟ in 2015 at Spring Ridge yielded 6.17 and 1.23 t/ha at the top and bottom slope sites, respectively (data not shown). The frost damage at the bottom of the slope reduced average grain yield of the six varieties by 1.91 t/ha across the three years (Table 4). There was minimal frost damage incurred on the two later planting dates as grain yields were similar between the top and bottom slope sites for the Liverpool plains and Gurley in all three years. Unlike the Liverpool Plains in 2016, there was no yield penalty in delaying planting date from late April until early June at Gurley (Table 4). This is compared to 2015, which had a hot dry spring, where the same delay in planting date resulted in a 1.88 t/ha reduction in grain yield (Table 4).

The optimum flowering window was retrospectively established by plotting grain yield against flowering date to see what period achieved the maximum grain yields. At Gurley in 2014 and 2015 the optimum flowering windows were generally 12-14 days from mid to late August for the top of slope site, whereas in 2016 the optimum flowering window was much wider (24 days) and began in early September (Table 4). The length of the optimum flowering window for the bottom slope site at Gurley was similar to the top slope for the respective years, however, it generally started 9-13 days later. The delayed optimum flowering window for the bottom slope sites was also observed on the Liverpool Plains where it started 10-22 days later than the top of the slope (Table 4). Optimum flowering windows on the Liverpool Plains for the top slope sites generally started around the beginning of September while the optimum flowering window for the bottom of the slope generally started around mid-September (Table 4).

Table 4. Average grain yield for LPB Dartⓟ, LPB Spitfireⓟ, Suntopⓟ, EGA Gregoryⓟ, LPB Lancerⓟ and EGA Eaglehawkⓟ plant across three planting dates at the top and bottom slope sites at the Liverpool Plains and Gurley and restrospective optimum flowering times for highest yield potential.

Site	Slope	Late April	Mid May	Early June	Optimum Flowering Window
Premer 2014	**Top**	5.24	4.28	3.00	1st Sep - 12th Sep
	Bottom	4.68	4.42	3.16	10th Sep - 20th Sep
Gurley 2014	**Top**	-	1.56	1.19	18th Aug - 3th Sep
	Bottom	1.26	1.60	1.42	28th Aug - 10th Sep
Spring Ridge 2015	**Top**	5.37	4.90	4.33	25th Aug - 5th Sep
	Bottom	4.53	5.18	4.60	16th Sep - 25th Sep
Gurley 2015	**Top**	5.25	4.56	3.37	11th Aug - 24th Aug
	Bottom	4.62	5.01	3.62	24th Aug - 9th Sep
Premer 2016	**Top**	7.52	7.25	6.18	8th Sep - 28th Sep
	Bottom	7.01	7.34	6.05	20th Sep - 10th Oct
Gurley 2016	**Top**	6.32	6.41	6.57	6th Sep - 30th Sep
	Bottom	5.98	6.56	6.51	15th Sep - 30th Sep

The 2015 season data for Spring Ridge and Gurley is presented below to demonstrate how the optimum flowering window was determined and how fine the line is between frost damage, particularly at the bottom of the slope. Further the 2015 season clearly illustrates the hot dry conditions during grain fill. At the Spring Ridge top slope the highest grain yields were achieved when varieties flowered between the 25th August and the 5th September. There were no frost events that occurred during this same period, with the last frost event occurring on the 18th August (Figure 2A). In the first week of October there were 5 consecutive days where maximum temperature exceeded 35°C (Figure 2B). Maximum temperatures exceeded 28°C everyday between the 28th September and the 22nd October (Figure 2B).

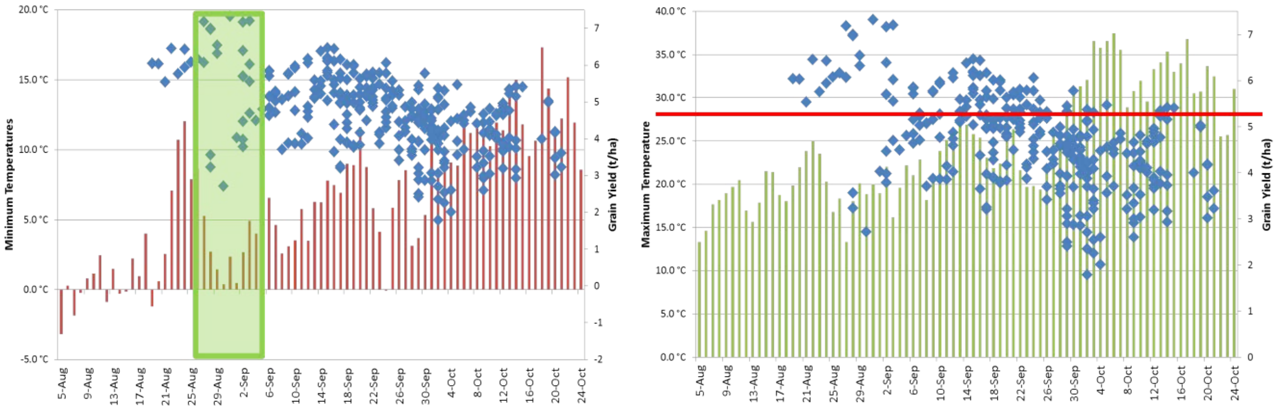

Figure 2. A) Minimum temperatures (red bars) and grain yield x anthesis date (blue diamonds) for individual plots for top slope at Spring Ridge in 2015. Green box indicates the retrospective optimum flowering date at site. **B)** Maximum temperatures (green bars) and grain yield x anthesis date (blue diamonds) for individual plots for top slope at Spring Ridge in 2015. Red line indicates 28 ^{o}C.

Retrospectively, the highest yields were achieved when varieties flowered between 15th and 25th September for the bottom slope site at Spring Ridge (Figure 3A). Unlike the top slope, the last frost at the bottom slope site occurred on the 30th September. Frost events in the last week of August appear to have had a significant impact on grain yields of varieties that have flowered prior to the 10th September (Figure 5). The extent of this frost damage was evident in LPB Dart in the field, where in excess of 90% of primary tillers had frost damage (Figure 3B).

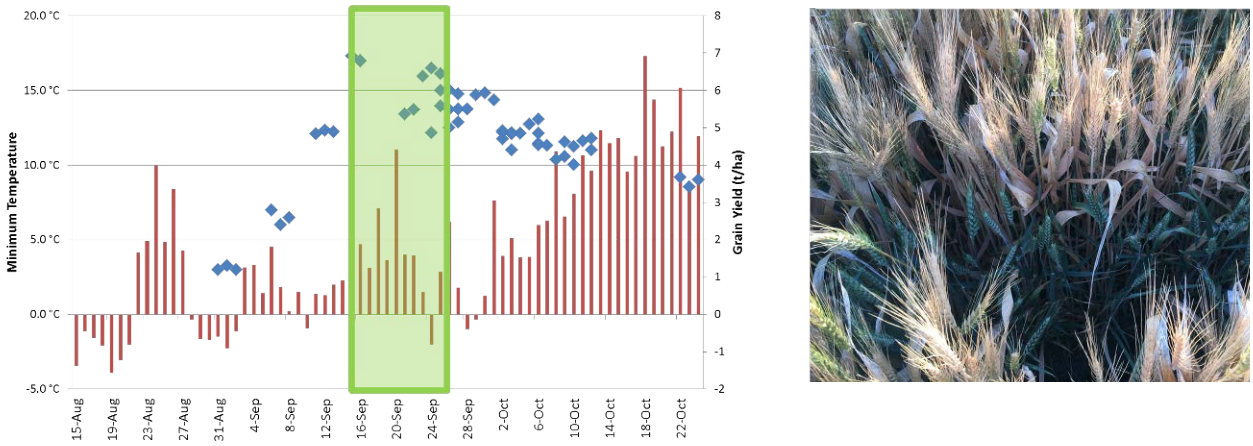

Figure 3. (A) Minimum temperatures (red bars) and grain yield x anthesis date (blue diamonds) for individual plots for bottom slope at Spring Ridge in 2015. Green box indicates the retrospective optimum flowering date at site. **(B)** Picture of frosted heads in LPB Dart plot at the bottom of the slope.

Maximum yields for top slope at Gurley were achieved when flowering dates occurred between the 11th August and the 23rd August (Figure 4A). There was one small frost event that occurred during this period. However, there were only two frost events that occurred near flowering that were lower than -0.5°C (28th July and 5th August) (Figure 4A). After the 28th October there were 13 consecutive days where maximum temperatures exceeded 28°C and 4 days where temperatures exceeded 35°C (Figure 4B).

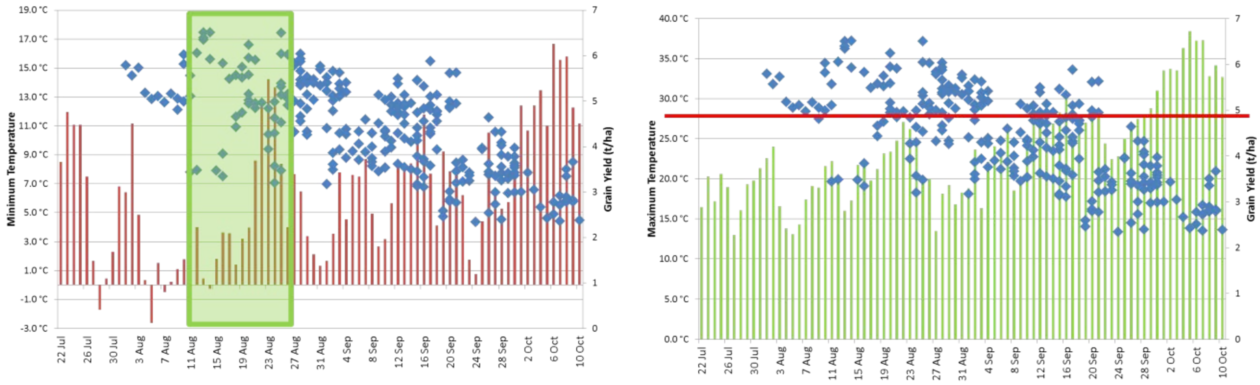

Figure 4. A) Minimum temperatures (red bars) and grain yield x anthesis date (blue diamonds) for individual plots for top slope at Gurley in 2015. Green box indicates the retrospective optimum flowering date at site. **B)** Maximum temperatures (green bars) and grain yield x anthesis date (blue diamonds) for individual plots for top slope at Gurley in 2015. Red line indicates 28 °C.

For the bottom slope the retrospective optimum flowering dates were between the 24th August and the 9th September. Interestingly, 4 frost events occurred in this same period (Figure 5). Unlike the top slope there were 17 frosts that occurred between the 27th July and the 9th August that had minimums below -0.5°C (Figure 5).

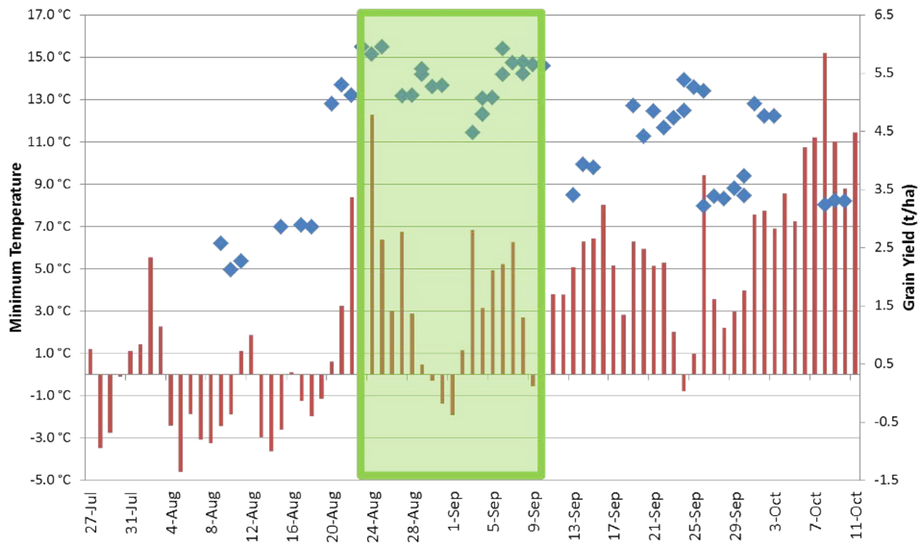

Figure 5. Minimum temperatures (red bars) and grain yield x anthesis date (blue diamonds) for individual plots for bottom slope at Gurley in 2015. Green box indicates the retrospective optimum flowering date at site

Discussion

The data collected in these trials demonstrates why there should be significant motivation to plant paddocks as early as possible to maximise optimal grain filling conditions while avoiding risk of frost damage. On the Liverpool plains assuming a wheat price of $250/t the late April planting date has created an additional $425/ha and $1155/ha net return compared to the mid May and early June planting dates, respectively at the top of the slope over three years. Even in 2016 when optimal spring conditions prevailed there was still a 1.34 t/ha yield penalty for delaying planting dates from late April to early June at the top of the slope on the Liverpool plains. There are few other management tools available to growers that can manipulate net returns to this extent. Admittedly, the 2014 and 2015 seasons exacerbated the impact of planting date due to well below average

September rain that was followed by extremely hot weather in early October. Both these factors would have contributed to restricting the grain filling period for long season varieties or later planting dates. For example at Gurley in 2015 a variety that flowered on the 20th August had an additional 31 days of favourable grain filling conditions compared to a variety that flower on the 20th September before the extremely hot temperatures started in the beginning October.

The two locations demonstrate that frost risk can vary greatly within the landscape, particularly with elevation differences. This represents an opportunity for growers to be able to plant earlier in certain parts of the landscape without necessarily increasing their exposure to frost risk. The top slope sites only had 30 and 20% of the frost events that occurred at the bottom slope on the Liverpool plains and Gurley, respectively. Not only are there less frost events but the frost severity is also greatly reduced. Top slope sites had 45% higher average minimum temperatures and only accumulated 11% of the time spent <0°C compared to the bottom of the slope when averaged across all sites and locations. The impact of this drastic difference in frost risk is evident on the April planting date in 2015 at both Spring Ridge and Gurley with the two quicker varieties, LPB Dart and LPB Spitfire. For the bottom slope LPB Dartɸ was 60 and 81% lower yielding compared to the top slope sown in late April at Gurley and Spring Ridge, respectively. Also on the late April plant LPB Spitfireɸ was 61 and 43% lower yielding at the bottom of the slope compared to the top slope site at Spring Ridge and Gurley, respectively. It was interesting to note that at both Spring Ridge and Gurley, Suntopɸ flowered approximately 5 days later than LPB Spitfireɸ yet grain yields were 2.4 and 2.7 t/ha higher, respectively. This suggests that 4-5 days difference in flowering date could be a difference of 50% in yield losses to frost damage. Varietal difference in tolerance to frost damage may in part also explain some of the differences between LPB Spitfire and Suntop. Despite the top slope sites at either Gurley or the Liverpool plains experiencing frost events during all three seasons there was not one instance where significant frost damage was recorded, even in the quickest variety, LPB Dartɸ. Therefore, even earlier planting dates were required at the top slope sites to incur yield penalties from frost.

The significant differences in minimum temperatures between top and bottom slope has also had an interesting impact on crop maturity. The greater number of frost events and severity has in turn slowed down the accumulation of GDD throughout the season, to the extent that the bottom slope at both locations accumulated over 150 GDD less than the top slope. As a direct result of this the crop maturity was delayed. The maturity delay is greatest on the early planting with and average delay of 11 days for varieties to reach flowering. This is interesting as the delay in maturity is actually helping to negate some of the frost risk at the bottom of the slope. In a majority of cases the optimum flowering window at both Gurley and Liverpool plains was 14 days later at the bottom of the slope compared to the top slope. Alarmingly, there were a number of instances where frost events had occurred during the optimum flowering window at the bottom slope sites for both locations. Although these frost events appear to have had little impact on grain yield in these years it does highlight the higher risk of incurring frost damage in these lower parts of the landscape. Furthermore, it highlights that frost events at lower elevations are persisting longer into the season, yet on set of potential heat stress is no different to higher elevations, thus reducing the length of the optimum flowering window.

Conclusions

As in previous experimental work these trials have demonstrated to benefits of early planting from a production and economic point of view. However, this work does demonstrate that elevation has a large impact on frost risk, which in turn represents an opportunity for growers to plant earlier in higher parts of the landscape without necessarily increasing the frost risk. Although the frost risk changes with elevation the risk of heat stress during grain fill does not change with maximum temperatures being similar for top and bottom slope sites. Therefore lower parts of the landscape have a narrower optimum flowering window. Lower minimum temperatures and a greater number of frost events in lower parts of the landscape reduce the accumulation of GDD and hence delays crop development. Despite the delayed development there is still a need to adjust planting date to achieve an acceptable level of frost and heat risk during grain fill. The paddocks selected to conduct these trials were selected because of their large variation in elevation, however they do demonstrate how frost risk varies significantly within the landscape and how difficult it may be to interpolate frost risk/planting decisions from the nearest weather station, which could be located some distance away. It is important to remember that elevation can be used as a valuable tool to evaluate frost risk but other factors such as drainage lines, aspect, tree lines and position in the landscape also need to be considered.

Acknowledgements

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Time of sowing (TOS) of cereals - drivers of phenology and matching variety to TOS in different environments.

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Notes

Farming systems - GM and $ return/mm water.

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Notes

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

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Key words

Nitrogen, efficiency, soil movement, timing

GRDC code

NGA00004

Take home messages

Over the 14 trials from 2014 to 2017, the efficiency of nitrogen (N) grain recovery from soil N was ~4 times that of fertiliser N that was applied in the year of cropping

Maintaining high soil N levels is critical for cereal production efficiency due to the poor fertiliser N grain recovery

Testing of grain, stubble and soil at harvest was able to account for a mean level of ~79% of the applied fertiliser N over 23 comparisons, however in 4 of the 23 comparisons, testing only accounted for 30-50% applied fertiliser N

The majority of the additional N at harvest was recovered in the soil and averaged ~65% of the applied quantity

The slow and shallow fertiliser N movement in soil is likely to be impacting on grain recovery efficiency

Strategies to get fertiliser N deeper, more quickly, may provide useful efficiencies in uptake and reduce potential losses

Strategies that can improve N contribution from the legume phase will be highly productive

Fallow N fertiliser applications are likely to provide a benefit over at planting application in years with low in-crop rainfall.

Background

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

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

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

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

Grain nitrogen recovery

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

1. Grain N recovery for each treatment was calculated as yield (kg/ha) x % protein/100 x 0.175

2. 'Net' grain N recovery was then calculated by deducting the grain N recovery in the untreated (unfertilised treatment)
3. % grain N recovery was calculated by dividing the net recovery by the amount of N applied

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

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

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

Key points

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

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

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

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

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

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

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

Key points

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

Situations of concern

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

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

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

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

Movement of N

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

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

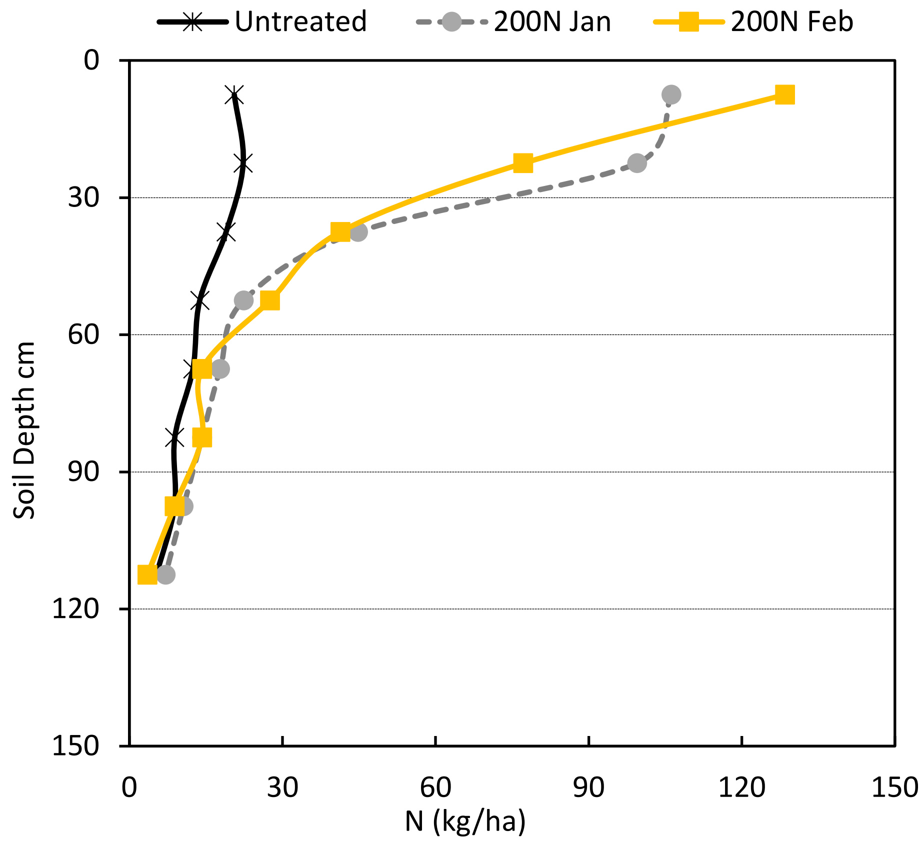


Figure 1. Soil distribution of N at Mullaley at planting (May 2017) following application of urea in January or February 2017. 175mm of rain was recorded between the January application and planting. 140mm of rain was recorded between the February application and planting.
(NB: Both N applications were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

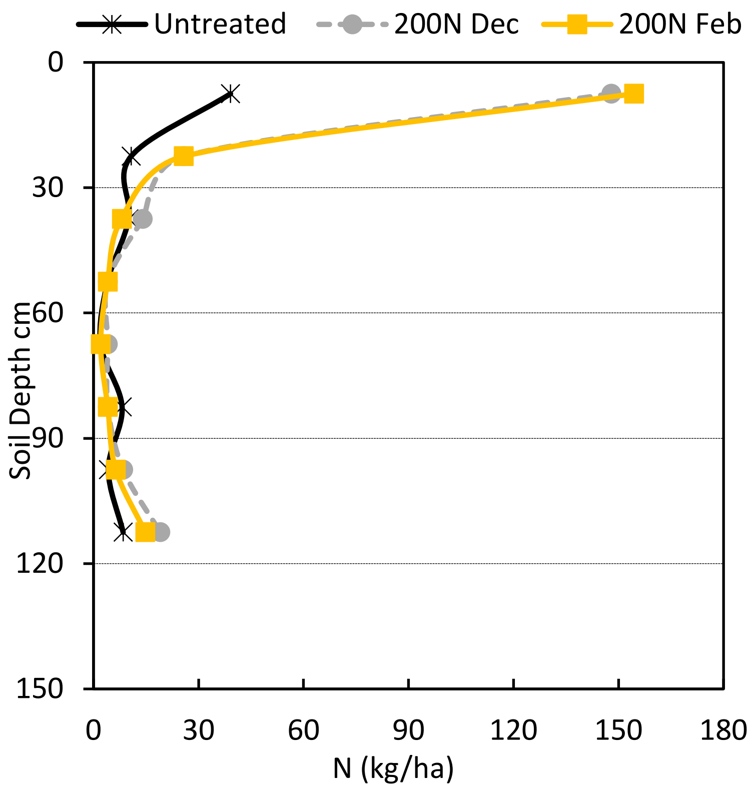


Figure 2. Soil distribution of N at Tulloona at planting (June 2016) following application of urea in December 2015 or February 2016. 225mm of rain was recorded between the December application (spread and incorporated) and planting. 65mm of rain was recorded between the February application (spread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

Key points

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

Implications of reduced N movement

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

Billa Billa 2017

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

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

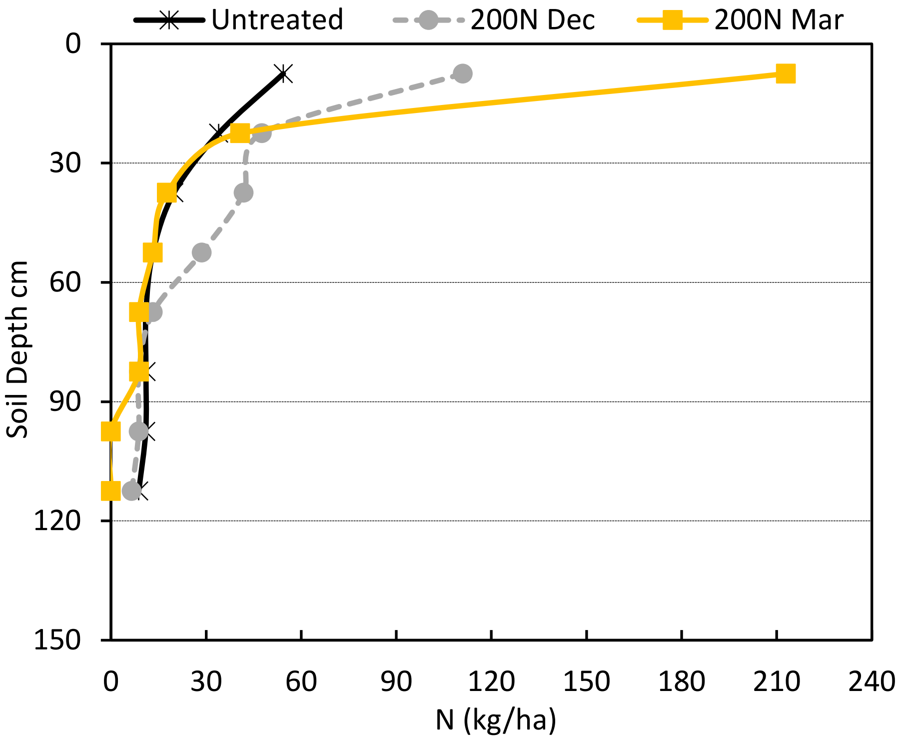
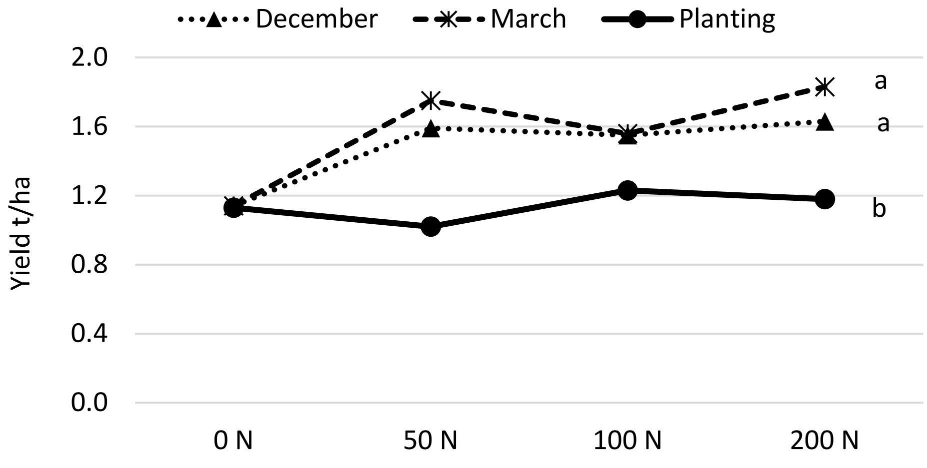


Figure 3. Soil distribution of N at Billa Billa at planting (May 2017) following application of urea in December 2016 or March 2017. 279mm of rain was recorded between the December application and planting. 154mm of rain was recorded between the March application and planting.
(NB: Both applications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

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



p<0.01, LSD=0.19

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

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

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

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

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

Key points

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

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

How much nitrogen was actually recovered at harvest?

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

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

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

Key points

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

Was nitrogen still available for the following crop?

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

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

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

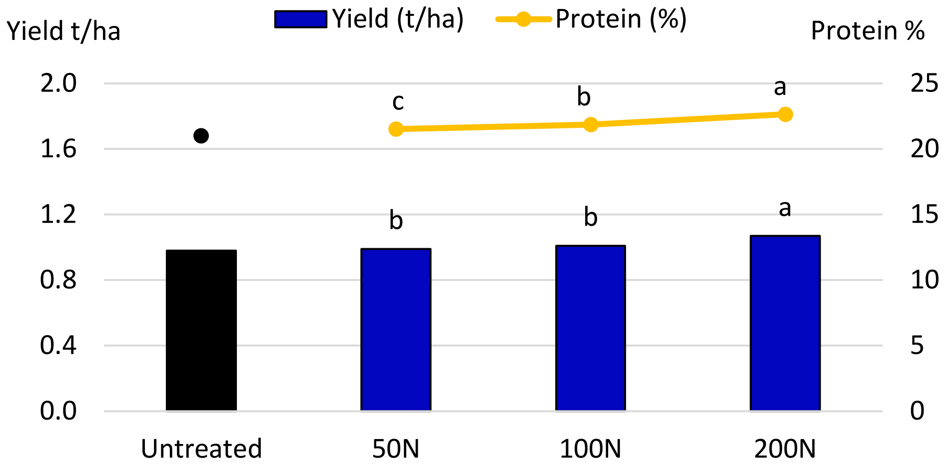
NB Sampling method - 4 individual 0-120cm depth cores taken per plot. Samples were separated into 0-30 and 30-90cm intervals with each depth bulked and a single sub sample taken for analysis. 4 replicates sampled in each treatment

Key points

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

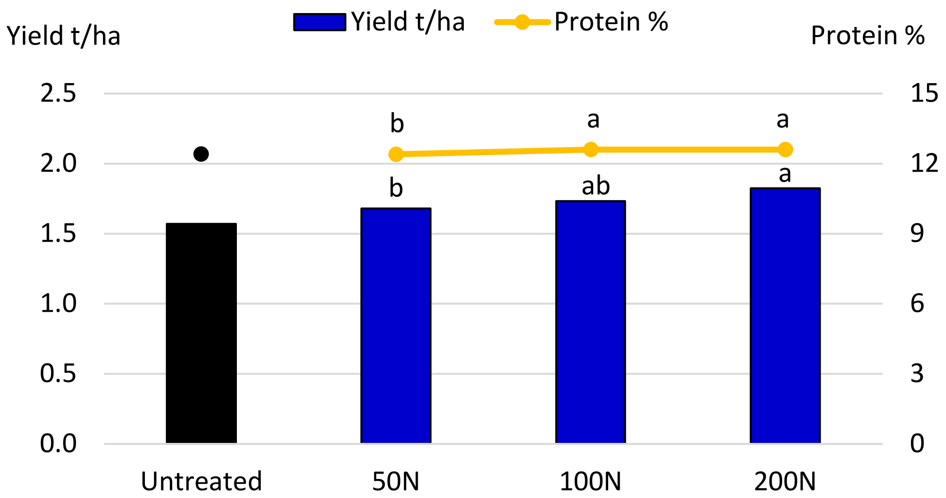
NB At the Tulloona site, ~60 % of the additional soil N was still found in the top 45cm with 45% found between 15 and 45cm. At the Macalister site, ~49 % of the additional soil N was still found in the top 45cm with 31% found between 15 and 45cm.

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



Yield: p=0.02, LSD=0.06 *Protein: p<0.01, LSD=0.29*

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



Yield: p=0.02, LSD=0.10 *Protein: p<0.01, LSD=0.1*

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

Key points

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

Economic impact

Tulloona

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

Macalister

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

Conclusions

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

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

Key industry challenges

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

Where to next?

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

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The interactions of nitrogen management on responses to phosphorus and potassium

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Key words

Nutrition, Central Queensland, nitrogen, response, phosphorus, potassium, uptake, sorghum

GRDC code

UQ00063 Regional soil testing guidelines for the northern grains region
UQ00066 Defining nitrogen response surfaces for Sorghum and Canola in the northern grains region

Take home messages

- Yield response to nitrogen can be compromised if deficiencies in phosphorus or potassium exist in the top 30cm of the soil profile
- Yield response to deep placement of phosphorus and potassium can also be compromised if nitrogen supply is restricted
- A comprehensive nutrition programme must consider the relative soil levels of nitrogen, phosphorus and potassium together to achieve full water limited yield.

Introduction

Trial work carried out over the last six years into the impact of phosphorus and potassium nutrition in dryland cropping production has revealed some interactions with nitrogen management that can have significant impacts on grain yield.

The supply of N to the plant can have major implications on the response to deep applied P and K fertiliser strategies and the reverse has also been apparent where response to N has been compromised by deficiencies in P and K nutrition. This work has reinforced the concept of Liebig's law of the minimum and given some practical evidence of this theory at work in the field.

While N nutrition has not been the focus of some of the trials conducted in the last six years, learnings from these data sets highlights some issues with not managing N, P and K together in a dryland farming system.

Experimental outline

This paper will discuss the results of three experiments operating on properties in Central Queensland dating back to 2013. Two of these experiments relate to nitrogen response work done with sorghum in 2012 and 2013 and the other data set relates to sorghum response to long term deep applied P experiment in 2018.

Experiment 1

Two nitrogen response sites were established in 2013; one near Dysart and one near Springsure creek. Both sites were set up with the same trial design using seven main treatments at both sites (Table 1). These rates of N were applied in 50cm bands (10cm deep) with additional background fertiliser applied offset from the main N band. The additional fertiliser included phosphorus (P), potassium (K), sulphur (S) and zinc (Zn) (Table 1) and this was applied to ensure that there were no other nutritionally compromising factors to the trial. In order to measure if these background elements could have an influence on the trial, two of the treatments was repeated (0N and 160N) without the background fertiliser.

Table 1. Treatments in nitrogen response trials at Dysart and Springsure creek in 2013 (kg/ha)

Treatment	N rate	P rate	K rate	S rate	Zn rate	Treatment Label
N1	0	20	50	20	0.5	0N+PKS
N2	40	20	50	20	0.5	40N+PKS
N3	60	20	50	20	0.5	60N+PKS
N4	80	20	50	20	0.5	80N+PKS
N5	160	20	50	20	0.5	160N+PKS
N6	0	0	0	0	0.5	0N
N7	160	0	0	0	0.5	160N

Treatment plots were set up within the grower-controlled traffic tramlines with each plot being 8m wide by 32m long and the total trial site was eight plots long per column (running parallel with the tramlines and old stubble rows) and six rows (8m blocks excluding the area in the tramlines) wide giving a total of 48 plots across six replicates.

Sorghum was planted by the grower with their own machinery with Dysart site being planted on the 16 January 2014 and the Springsure creek site planted on the 7 February 2014. Grain yield measurements were taken with a two-metre-wide plot header on the 10 June 2014 (Dysart) and 2 July 2014 (Springsure creek).

Experiment 2

Two nitrogen and sulphur response sites were established in 2012; one near the area of Fernlees, north of Springsure and the other in the Lilyvale district between Emerald and Capella. Both sites were set up with the same trial design using a completely randomised block design and combining nitrogen and sulphur treatments plots together in the one trial. Treatments were either a base rate of sulfur with varying rates of N or a base rate of N with varying rates of sulfur (Table 2).

Table 2. Treatments in nitrogen and sulphur response trials at Fernlees and Lilyvale in 2012

Treatment Labels	S Rate (kg/ha)	N Rate (kg/ha)
0N 0S	0	0
10N 12S	12	10
25N 12S	12	25
40N 12S	12	40
55N 12S	12	55
70N 12S	12	70
85N 12S	12	85
100N 12S	12	100
75N 0S	0	75
75N 6S	6	75
75N 12S	12	75
75N 18S	18	75
75N 24S	24	75

There were 13 treatments used (including control), but there were 16 plots per replicate with three extra control plots used in each replicate. The plots were 6 m wide by 32 m long and the trial was setup with eight plots long by eight plots wide across four replicates giving a total of 64 plots.

The only other nutrition applied to these trial sites was a starter rate of P at planting which was applied as Triple Superphosphate, applied offset to the planting row at a rate of 60kg/ha. The trial was planted by Pacific Seeds staff using their trials planter on the 9 and 11 February 2013. Harvesting was competed with a two-metre plot harvester on the 29 and 30 July 2013.

Experiment 3

A long-term nutrition trial site was established near Dysart in 2013. While this site had multiple nutrition trials established side by side, this data set is only concerned with the deep placement P trial. The trial is a typical example of deep banded P trials that have been set up across multiple trial sites in CQ over the last six years. The trial involves the response to four different P rates (0, 10, 20 and 40 kg P/ha) with background rates of N, K, S and Zn applied to offset any other major nutrient deficiencies (Table 3). The trial also has three other treatments that use the highest and lowest rate of P without any background fertiliser applied (0P-KS, 40P-KS) as well as a farmer reference (FR) treatment that represents the grower co-operator commercial operations and has had no experimental applications of fertiliser applied (Table 3).

The performance of these treatments have been monitored over six years and six crops (planted by the grower on this trial site since 2013). Of interest to this paper is the differences in responses between two sorghum crops grown in the 2016 and 2018 seasons.

Table 3. Treatment list of Dysart trial looking at response to four different P rates (0, 10, 20 and 40 kg P/ha) with background rates of N, K, S and Zn applied to offset any other major nutrient deficiencies. The trial also has three other treatments that use the highest and lowest rate of P without any background fertiliser applied (0P-KS, 40P-KS) as well as a farmer reference (FR)

Treatment	N rate (kg/ha)	P rate (kg/ha)	K rate (kg/ha)	S rate (kg/ha)	Zn rate (kg/ha)	Treatment Label
P1	80	0	50	20	0.5	0P+NKS
P2	80	10	50	20	0.5	10P+NKS
P3	80	20	50	20	0.5	20P+NKS
P4	80	40	50	20	0.5	40P+NKS
P5	80	0	0	0	0.5	0P+N
P6	80	40	0	0	0.5	40P+N
P7	-	-	-	-	-	FR

Results

Experiment 1

Although the mean grain yields for these N response trials (Figure 1) show no significant difference in rate response to applied N; but it does show a significant difference between those treatments that have no background fertiliser (0N versus 0N-PKS, 160N versus 160N-PKS).

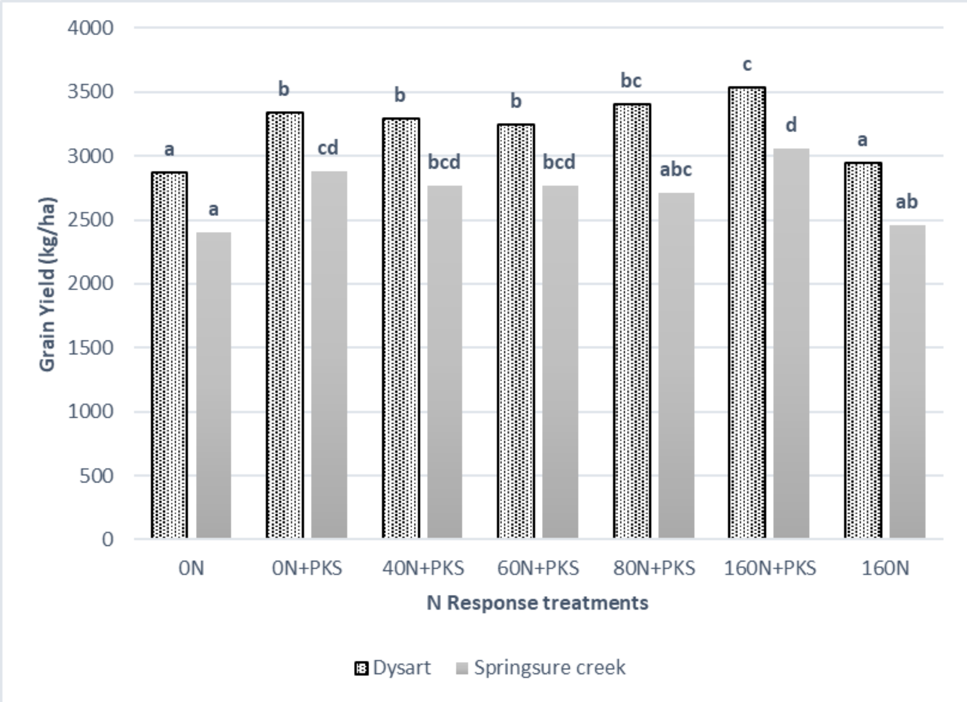

Figure 1. Mean grain yields for N treatments in 2013 sorghum trials at Springsure creek and Dysart. Means with the same letters are not significantly different. Least significant differences (P=5%) are only attributable within each trial, there is no cross-site analysis
(Dysart LSD=175, Springsure creek LSD =342)

The lack of background fertiliser has reduced the yield by ~500 kg/ha (16-24%). Comparing just the treatments that had the background nutrition withheld shows a significant difference in total N uptake for the plant (Figure 2). It is clear that the plants ability to utilise extra N in the soil profile is impacted by one or more of the background nutrients (P, K, S). In relative terms the background nutrients have increased N uptake by ~13% at Dysart and ~20% at Springsure creek.

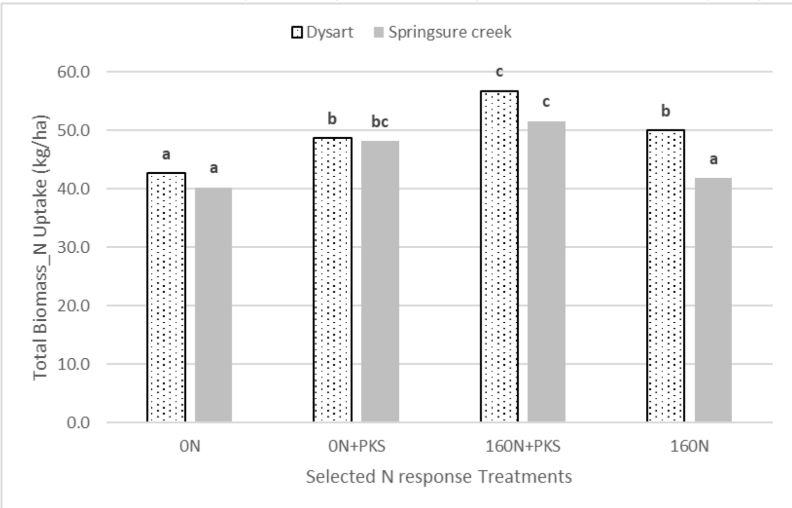

Figure 2. Mean N uptake amounts for total biomass in treatments comparing with and without background fertiliser applied. Means with the same letters are not significantly different. Least significant differences (P=5%) are only attributable within each trial, there is no cross-site analysis (Dysart LSD =4.77, Springsure creek LSD =4.05).

While it is impossible to know which background nutrient has had the most effect from this information, given the responses that have been gained from P on its own in the other trials at this site then it is highly likely that it is P in the background nutrition that is having the largest impact on the uptake of N in these sorghum plants.

Experiment 2

In this experiment we are comparing the performance of N response across two sites even though there is no cross-site analysis recorded with this data. The contrast is quite large and the evidence surrounding these sites does provide a strong indicator of the interaction between N, P and K.

Both sites are cracking vertisols although Fernlees has some alluvial influences in its formation and the Lilyvale soil is shallower and derived from basalt weathering. Both sites had similar starting N and in-crop rainfall (Table 4) but starting moisture was more limited at the Fernlees site (Table 4). Neither trial site had a full profile at planting but good moisture levels in the top 50cm made it possible to plant with some confidence.

Table 4. Summary of the agronomic characteristics of the trial sites

Site	Depth	Nitrates	Colwell P	K	Total profile N (0-120cm)	In-crop Rainfall	Starting Water
	cm	mg/kg	mg/kg	meq/100g	kg/ha	(mm)	(mm)
Fernlees	0-10	3	6	0.22	36	275	87
	10-30	5	3	0.07			
Lilyvale	0-10	5	18	1.25	30	242	100
	10-30	4	6	0.56			

In relation to P and K nutrition these two sites had some natural differences. Most obvious is that K levels at the Lilyvale site were unlimiting whereas the Fernlees site was more marginal in the top 10cm and deficient in the 10-30cm zone (Table 4). P levels were also limiting in both sites although the Lilyvale site did have adequate levels of P in the top 10cm and a reasonable rate of starter fertiliser was applied at planting.

Grain yield data (Figure 3) would suggest that the Lilyvale site responded well to the increasing rates of N applied as small plot treatments; whereas the Fernlees site had no response at all, even at the highest N rates. The starting N supply (Table 4) and the amount of in-crop rainfall would suggest that both sites should respond to N. It is interesting to note that both sites recorded similar yields in the control plots which would suggest that agronomically the sites are not too different.

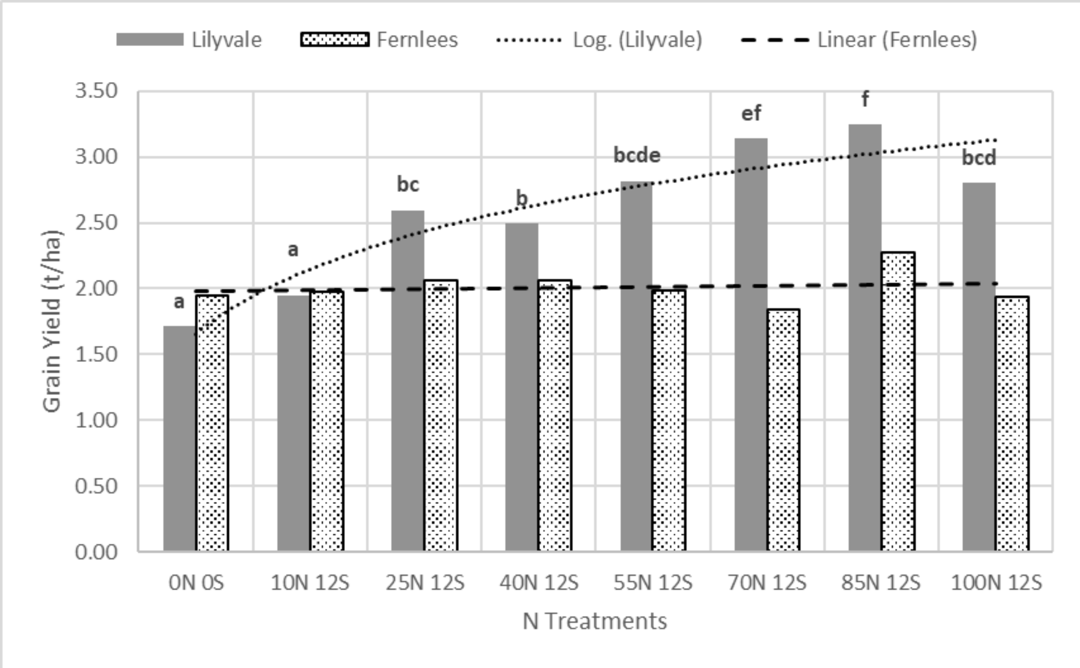

Figure 3. Mean grain yields for N response treatments across both the Lilyvale and Fernlees trial sites. Means with the same letters are not significantly different. Least significant differences (P=5%) are only attributable within each trial, there is no cross site analysis (Lilyvale LSD =0.333, Fernlees LSD =n.s)

Given both sites were planted to the same variety within two days of each other it is difficult to understand such a large discrepancy in responses. Chemistry analysis of the total biomass of the crop (Figure 4A and 4B) does give some clues on what the major influence might be in this situation.

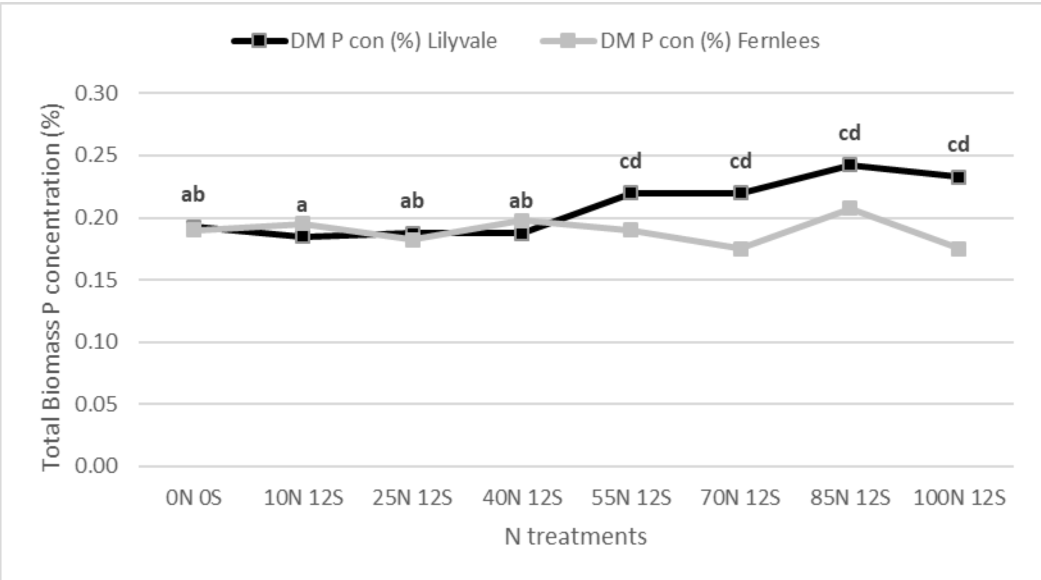

Figure 4A. Mean P concentrations for total biomass across N response treatments in both trial sites. Means with the same letters are not significantly different. Least significant differences (P=5%) are only attributable within each trial, there is no cross site analysis
(Lilyvale LSD =0.032, Fernlees LSD =n.s)

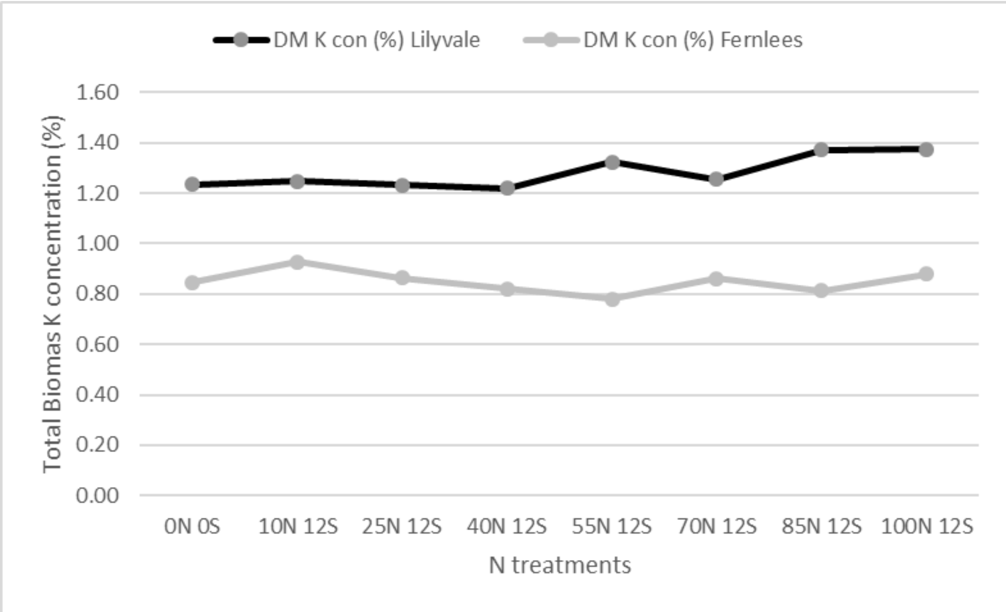

Figure 4B. Mean K concentrations in total biomass across N response treatments in both trial sites. Least significant differences (P=5%) are only attributable within each trial, there is no cross site analysis (Lilyvale LSD =n.s, Fernlees LSD =n.s)

Plant tissue analysis for P (Figure 4A) reveals both sites had access and took up similar levels of this nutrient even though P concentration in the plant increased at higher N rates at the Lilyvale site. Plant tissue analysis has revealed a large discrepancy in K concentration (Figure 4B) in the plant regardless of N treatment. The differences in control plots shows that the natural level of K uptake in the crop were very different (46%) between the two sites especially given the same species of crop and the same variety. Soil tests show (Table 4) there is a clear difference in K nutrition status.

The relative uniformity of K in the plant regardless of N status may suggest that the uniformity in grain yield across all N treatments maybe due to the lack of K nutrition. A secondary piece of evidence is the N concentration in the plant at both sites (Figure 5). The N concentration in tissue analysis at the Fernless site shows higher concentration in the control plots which would suggest the Fernlees site had slightly better access and uptake of N in its natural state, but grain yields were similar (Figure 3). Increasing N rates benefited the Lilyvale site with increasing grain yield and small significant differences in N uptake in biomass. The Fernlees site has also had some small increases in N uptake but this has not been able to convert into grain yield.

The natural conclusion is that the poor supply of K has made a significant impact on the plants ability to convert the extra N into grain yield.

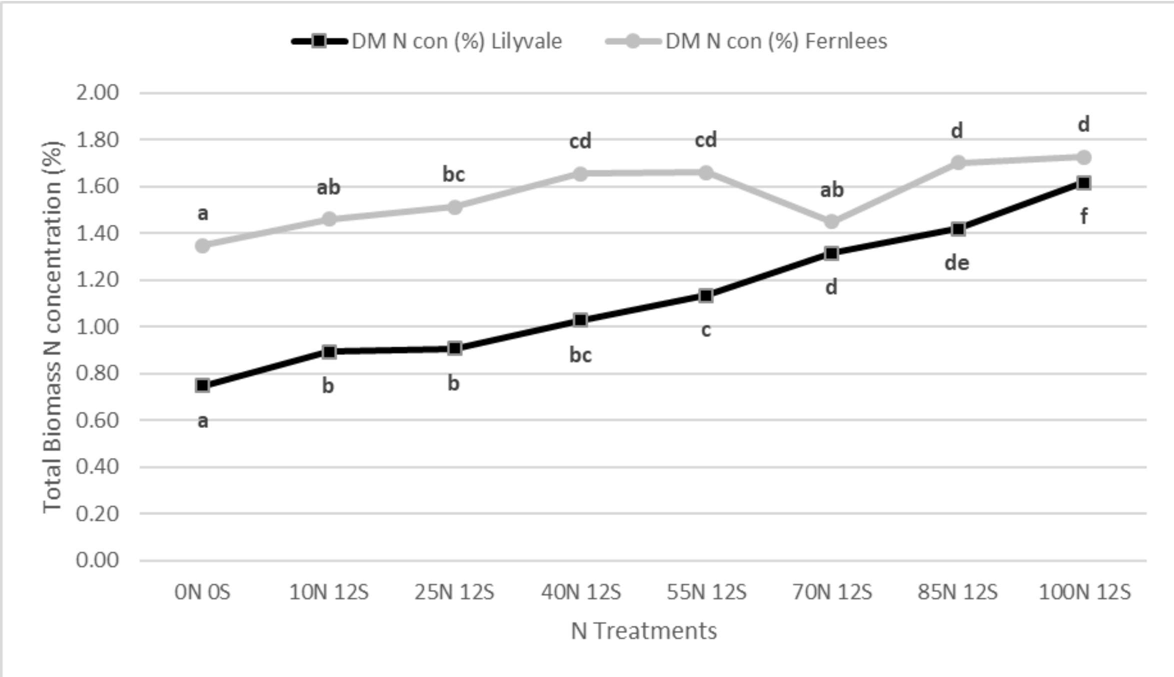

Figure 5. Mean N concentrations in total biomass across all N response treatments in both trial sites. Means with the same letters are not significantly different. Least significant differences (P=5%) are only attributable within each trial, there is no cross-site analysis (Lilyvale LSD =0.1507, Fernlees LSD =0.1503)

Experiment 3

This data relates to a deep banded P experiment conducted at Dysart involving two sorghum crops grown in 2016 and 2018. The results demonstrate a mark difference in performance of the deep P treatments coinciding with large differences in grain protein.

Table 5. Summary of agronomic characteristics for sorghum crops grown in 2016 and 2018 on deep P trial.

	Planting Date	Harvest Date	Starting water 0-120cm (mm)	Starting N 0-120cm (kg/ha)	In-crop Rainfall (mm)
2016 Sorghum	17/02/2016	7/07/2016	191	27	202
2018 Sorghum	13/02/2018	21/06/2018	237	196	159

Both sorghum crops experienced similar conditions in terms of planting and harvesting (Table 5). Starting soil water differences were balanced out by in-crop rainfall for both crops so crop conditions were similar. The one major difference is the starting N figures which shows the 2016 crop had very low N conditions at planting (Table 5).

The 2016 sorghum crop did have 100 kg Urea /ha applied but it was three weeks after planting as a sidedress application. The 2018 sorghum crop had 200 kg Urea/ha applied in the fallow preceding summer rainfall and planting in February.

Grain protein data (Figure 6) shows a consistent difference in grain protein between the two years (mean 8.1%, 2016 to 11.7%, 2018). These protein levels were uniform across deep P treatments even though grain yields were significantly different between treatments.

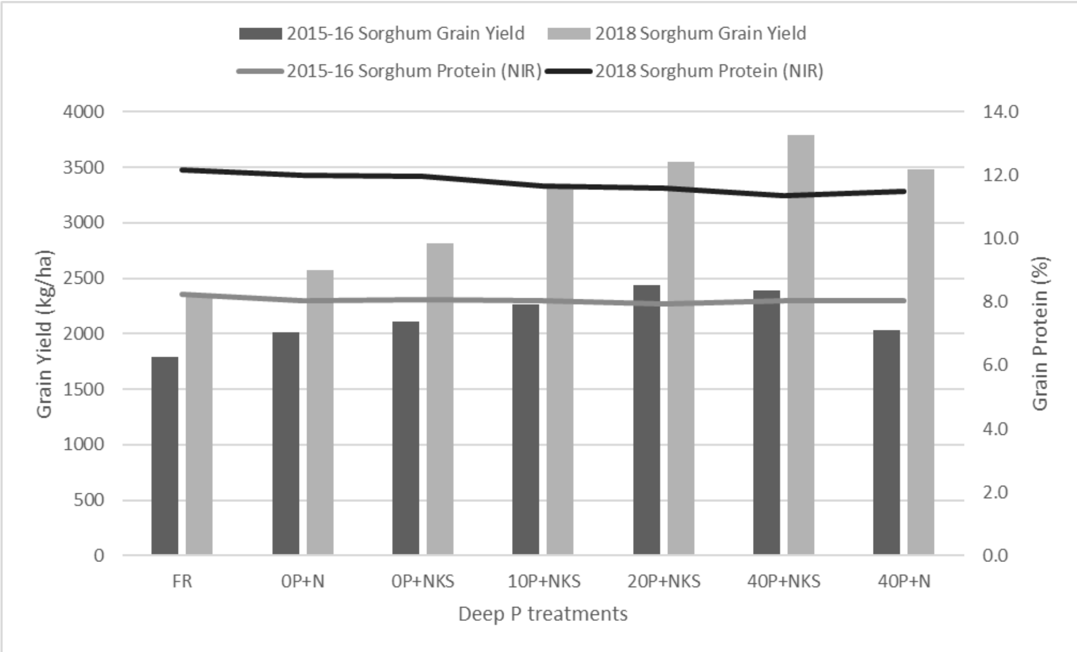

Figure 6. Mean grain yields for 2016 and 2018 sorghum crops across the deep P trial plus associated mean grain protein levels across treatments. Means with same letters are not significantly different. Least significant differences (P=5%) are only attributable within each trial, there is no cross-year analysis (2015-16 Sorghum LSD =253, 2018 Sorghum LSD =396)

While this data has not been analysed across years the relative differences are large between the two crops from the same plots (Figure 7), with the 2018 crop almost doubling the relative yield difference from 2016. The fact that that the 2018 crop is the fifth crop grown on the trial site would lead to an expectation that the yield response would be declining in relation to the deep treatments however in this case the opposite has occurred and the main difference is the supply of nitrate in the soil profile (Table 5) and the uptake of N in the plant demonstrated by the low protein figures (Figure 6).

This piece of evidence would suggest that the N supply can have a major impact on the plants response to phosphorous on deficient soils.

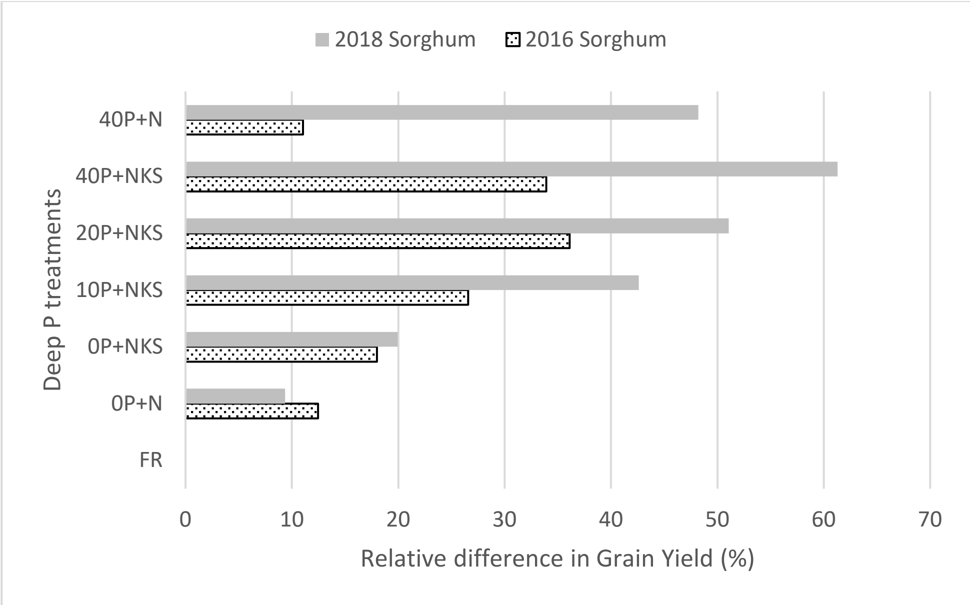

Figure 7. Relative differences in grain yields across P treatments as a percentage of the FR baseline across 2016 and 2018 sorghum crops.

Summary

The three trials highlighted in this paper have each shown the real impact of not balancing up macro nutrient supply in the soil profile. The data demonstrates that P and K can prevent increases in yields from N application as well as a lack of N supply can reduce the response to P and K in deficient situations. Deficiencies in either N, P, or K have the capacity to limit yield and although this is known intuitively (Liebig's Law of the Minimum), direct evidence of yield loss shows the real numbers around the impact on grain production. Expenditure on fertiliser can be unprofitable if there has not been enough consideration given to the level of all macro nutrients in the soil profile.

Several trial sites in CQ have shown that multiple deficiencies can exist in soil types that have high water holding capacity. Water limited yield cannot be achieved unless all major nutrient deficiencies are dealt with at the same time.

Soil testing is imperative to make sure that all macro nutrient levels are well identified and ensure that the most appropriate fertiliser strategy is adopted. Unfortunately, management of macro nutrient deficiencies are not all the same. N and S need to be treated differently to P and K but all four are essential to achieve water limited yield.

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Presented at Capella only

Panel discussion - managing nutrition for the 2020 summer crop

Notes

Presented at Capella only

Chemical residues/MRL's - impact, understanding and potential trade issues.

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Presented at Moura only

Local experience using cover crops

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Notes

Presented at Moura only

Mungbean agronomy research for Central Queensland

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Key words

mungbeans, rows, population, sowing, windows, weather, yields

GRDC code

UQ00067 Queensland Pulse Agronomy Initiative

Take home messages

- Mungbeans can be grown in any row spacing from 25cm to 100cm without any yield penalty up to 1.5 t/ha. Yield gains can be made by planting in 25 to 50cm rows in conditions that allow for yields above 1.5 t/ha
- Populations below 10 plants/m² will suffer yield penalties at all row spacings. Populations between 20 – 30 plants/m² will maximise yields in most yield brackets. The highest irrigated yields have been achieved with 35 – 45 plants/m² on narrow rows
- Planting mungbeans later in the summer window (February) can have significant yield benefits by avoiding high evaporative conditions leading up to flowering and during flowering.

Introduction

The Queensland Pulse Agronomy Initiative project funded a series of trials across Southern and Central Queensland from 2013 to 2018. These trials examined a range of issues that related to a physiology approach to improving yield and reliability in a broadacre crops by combining genetics (G) by environment (E) by management (M). The genetic component is represented by current breeding programmes in both mungbeans and chickpeas and the latest commercial releases. The environmental component relates to climate and weather which can be quite different across growing regions such as the inner Darling Downs of southern Queensland (SQ) versus the central highlands of Central Queensland (CQ).

The management component is all those things that agronomists and growers can control. In this particular project, experiments were designed to combine components like row spacing, plant populations and time of sowing to find the 'sweet spot' for mungbean production. While there was a number of trials conducted in this five-year period, this paper will focus on two experiments that were carried out in 2016 and 2017 to illustrate some of the general outcomes of this work and provide a typical data set for recommendations.

Experimental outline

Experiment 1 (2015-16 summer)

This trial was conducted at the research facility based at the Emerald Agricultural College. Mungbeans were planted at three sowing dates; 18 December, 13 January and 18 February, with each time of sowing (TOS) being a standalone block split into three row spacing (25 cm, 50 cm, and 100 cm). Each row spacing block was split in half and one side had irrigation applied through hand shift spray lines. These two halves were then each split into four population treatments (10, 20, 30 and 40 plants/m²). One variety was used across the trial (Jade-AU⦶) and all treatments within each time of sowing (TOS) block were replicated three times. Each plot was 4 meters wide by 12 meters long and Supreme Z® was applied with the seed at 30 kg/ha. The trial site had a pre-plant fertiliser application of CK55(S)® at 150 kg/ha on 50 cm spacing.

Due to ongoing dry conditions and a short turnaround from a wheat cover crop, the trial block was pre-irrigated twice before the first planting, ensuring there were consistent moisture conditions to plant into. The second and third plantings were planted on rainfall.

Due to some difficult conditions in December, established plant populations did not meet targeted populations (Figure 1). Significant differences were maintained between the 10, 20 and 30 populations but the 40 plants/m² ended up being similar to the 30 plants/m² populations. The January and February plantings were much better and established populations were close to target.

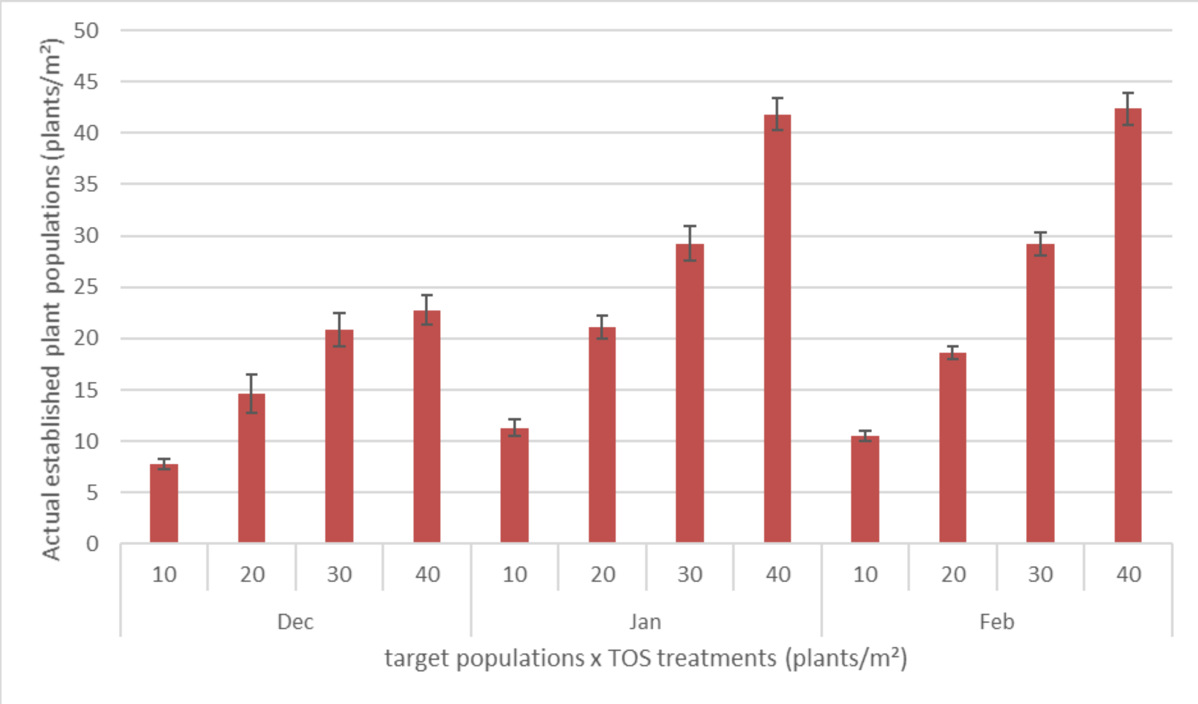

Figure 1. Target populations versus established populations across time of sowing.

Experiment 2 (2017-2018 Summer)

A trial was conducted at the research facility based at the Emerald Agricultural College. Mungbeans were planted at three sowing dates; 8 December, 18 January and 2 March, with each TOS block being planted twice in each replicate so that one block could be supplemented with sprinkler irrigation (soil water conditions) with the other being left as dryland (or rainfed). Each of these blocks where then split into two row spacing (25 cm, 100 cm) and each row spacing block was further split into 8 treatments which consisted of two varieties (Jade⦶, Satin II⦶) by four foliar nitrogen (N) treatments (0, 10, 20 and 30 kg/ha).

Each plot was 2 meters wide by 16 meters long and Supreme Z® fertiliser was applied with the seed at 30 kg/ha at planting.

Due to ongoing dry conditions and a short turnaround from a sorghum cover crop, the trial block was pre irrigated twice before the first planting, ensuring there were consistent moisture conditions to plant into. The December and March TOS were planted with irrigation while the January TOS was planted on rainfall.

A number of measurements were recorded throughout the life of the crop. These included plant counts, light interception readings, dry matter cuts, hand harvest, machine harvest and weather data that was logged every 15 minutes. Also measured was starting plant available water content (PAWC) and a full soil analysis at planting.

Results

Experiment 1 (2015-16 summer)

There were large blocks of data collected from this trial including weather information, dry matter yields, grain yields, neutron probe readings, hand harvest yields and grain weight and protein data; for the purpose of this paper the results presented will focus on the yield performance of the row spacing and population treatments across the three times of sowing under irrigated and dryland conditions.

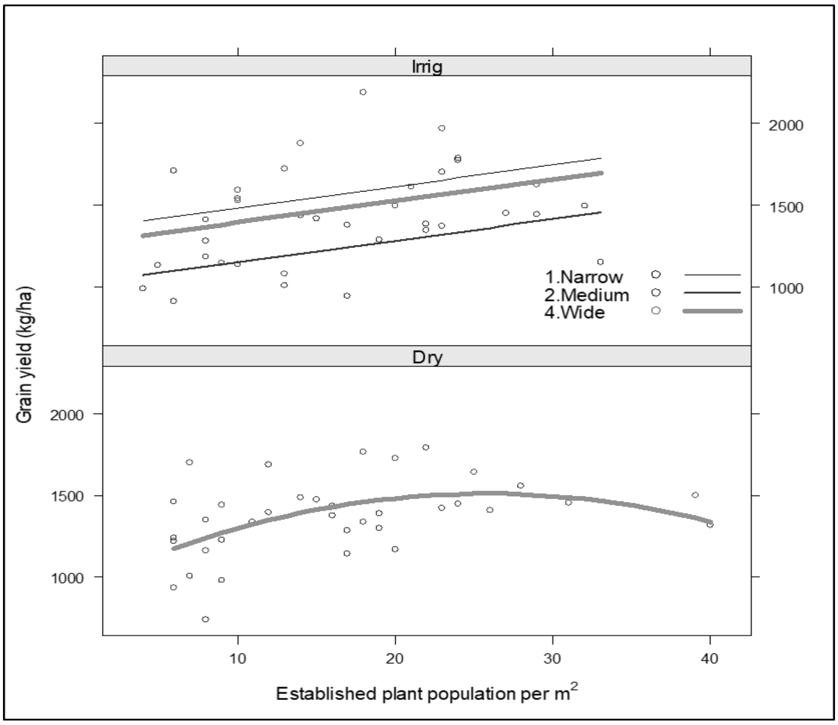

Figure 2A: Grain yield data analysed using linear mixed models within TOS1 (December) for population and row spacing effect across dryland and irrigated treatments
(Row spacing; narrow = 25cm, medium = 50cm, wide = 100cm)

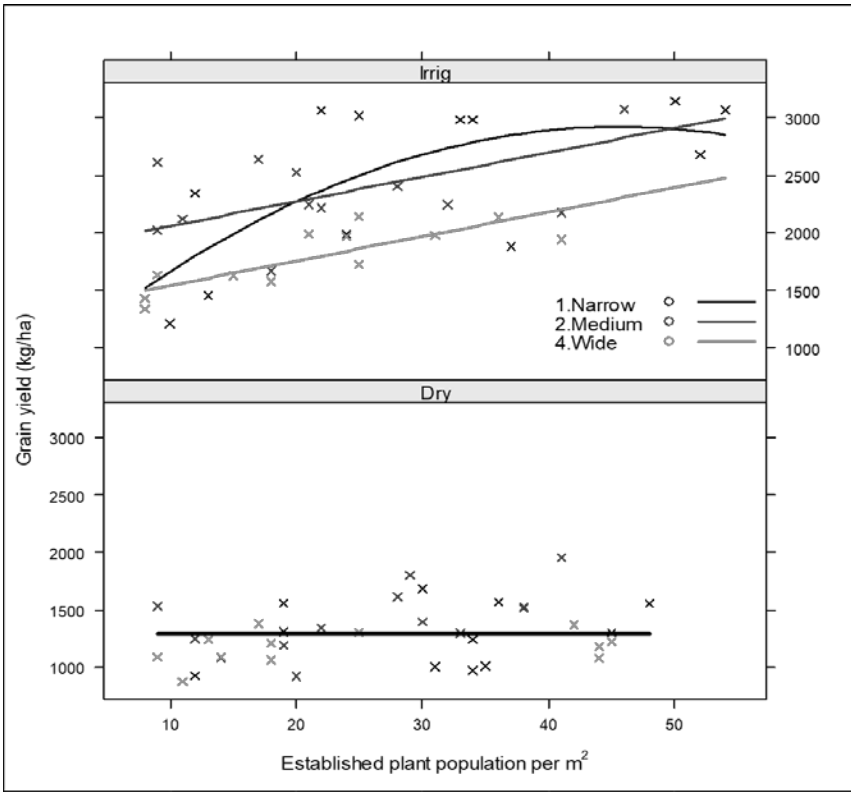

Figure 2B: Grain yield data analysed using linear mixed models within TOS2 (January) for population and row spacing effect across dryland and irrigated treatments.
(Row spacing; narrow = 25cm, medium = 50cm, wide = 100cm)

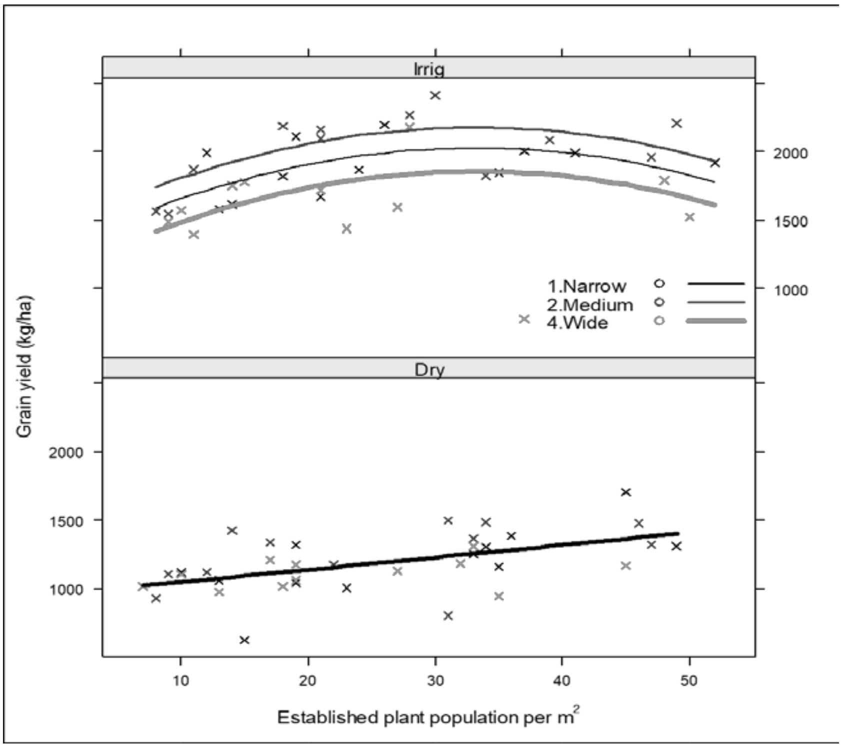

Figure 2C: Grain yield data analysed using linear mixed models within TOS3 (February) for population and row spacing effect across dryland and irrigated treatments.
(Row spacing; narrow = 25cm, medium = 50cm, wide = 100cm)

Grain yield data (Figure 2A-2C) would suggest there is no significant difference between row spacing in the dryland treatments. In all three TOS the dryland yield range was between 0.8 to 1.5 t/ha. This would suggest that within this yield bracket row spacing has no real impact on achieving those yields.

Population impact on yield in the dryland treatments are small (Figure 2C and 2A) or not significant at all (Figure 2B). This would indicate that plant compensation within various populations would seem to be good enough to achieve this water limited yields of between 0.8 to 1.5 t/ha.

When extra water is added through irrigation or rainfall there are more positive differences in both population and row spacing. Depending on the TOS there is a significant difference in the curves for row spacing in TOS2 (January) and TOS3 (February). Generally, the response is linear to population within each of these row spacing. The narrow (25cm) and medium (50cm) rows have a significant advantage at all populations while the 25cm rows can have a quadratic relationship where the lowest populations have a significant downside in yield compared to where yield peaks at 45 plants/m².

TOS may have an impact on the size and type of response. The December TOS (TOS1) had a basic linear response to population and February (TOS3) had a quadratic response to population and January (TOS2) had a bit of both. Yield brackets are different between each TOS with January (TOS2) being 1.5 to 3 t/ha whereas the other two TOS are in the 1.0 to 2.2 t/ha.

The overall trend suggests population and row spacing have limited impact up to 1.5 t/ha although there is generally a drop off in yield below 10 plants/m². When yields climb above 1.5 t/ha and this generally requires irrigation or well time rainfall events the narrow rows (25-50cm) and higher populations (35 to 45 plants/m²) can make significant improvements to yield.

Experiment 2 (2016-2017 Summer)

There are many aspects to the data collected for this trial, however in relation to this paper the data presented will focus on the TOS aspects of this trial and the differences that TOS has made to the performance of the crop.

Average grain yields across all three TOS (December, January and March) for both row spacing (Figure 3B) and variety (Figure 3A) would indicate that the later TOS (March) was the most successful in maximising grain yield. The only exception to this was Jade⦶ and the 100cm rows which plateau in January and March.

Similarly, the difference between those plots that got irrigated and the rainfed plots were greatest in the early TOS (December) while in January and March the effect was mostly non-significant. This response has been compromised by the fact that the January TOS received 104mm of rainfall after the start of flowering, and the March TOS received 164mm before the start of flowering. In contrast the December TOS received 72mm before flowering and 30mm after flowering.

As with all TOS trials the pattern of weather conditions is paramount in understanding the differences in crop performance.

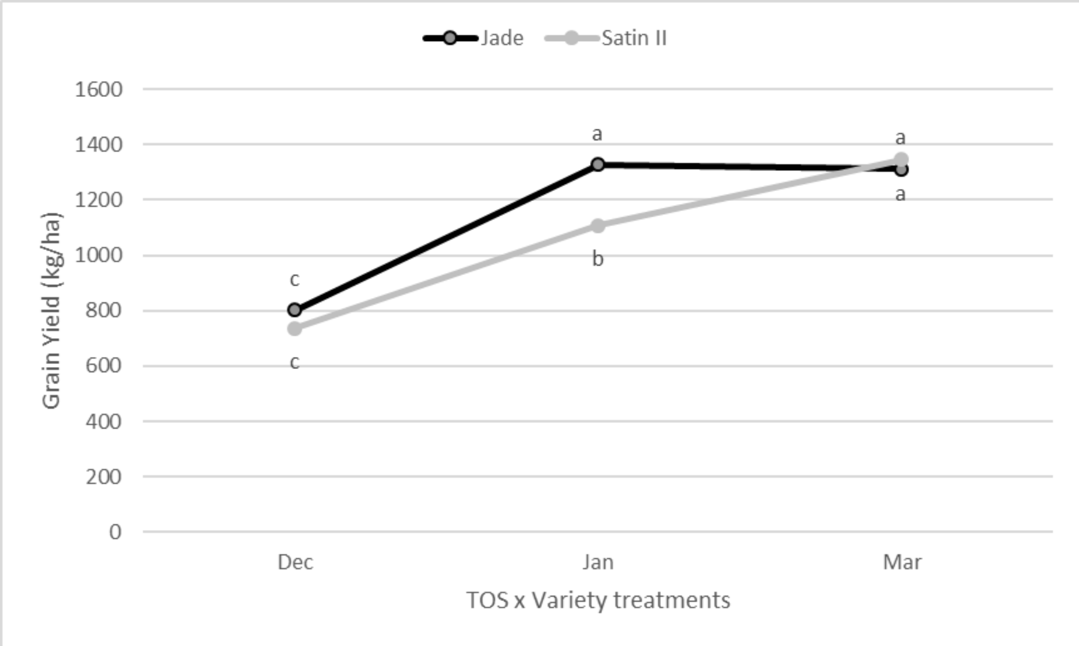

Figure 3A: Comparison of mean grain yields for varieties across three times of sowing (TOS). Means with the same letters are not significantly different at the P=5% level (LSD = 159.4).

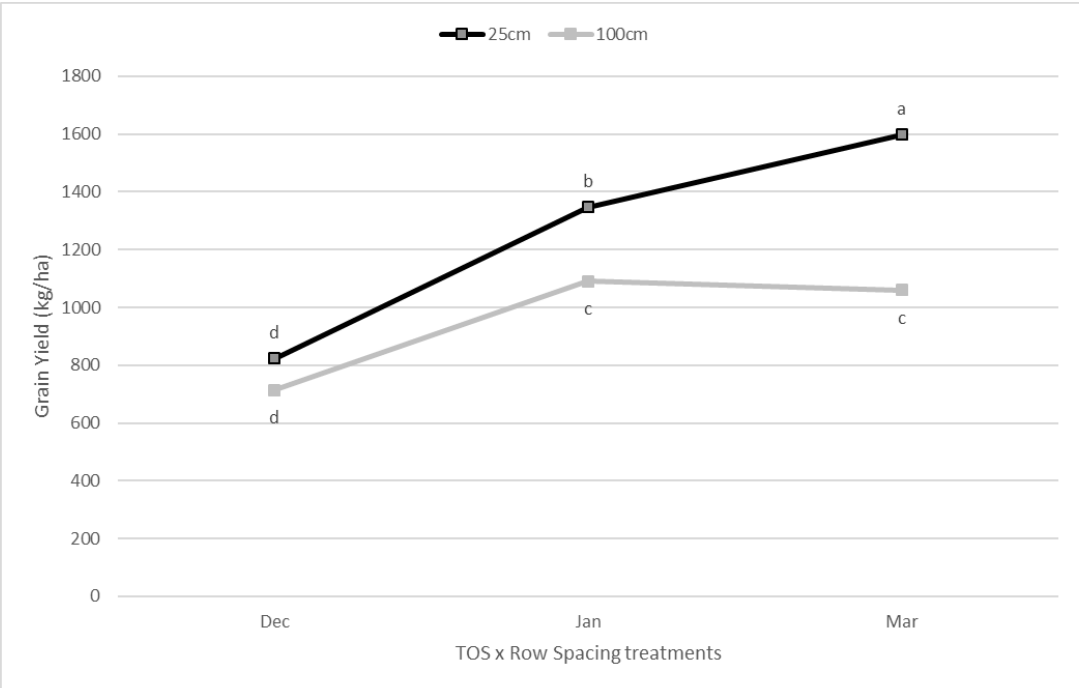

Figure 3B: Comparison of mean grain yields for row spacing across three times of sowing (TOS). Means with the same letters are not significantly different at the P=5% level (LSD = 179.6).

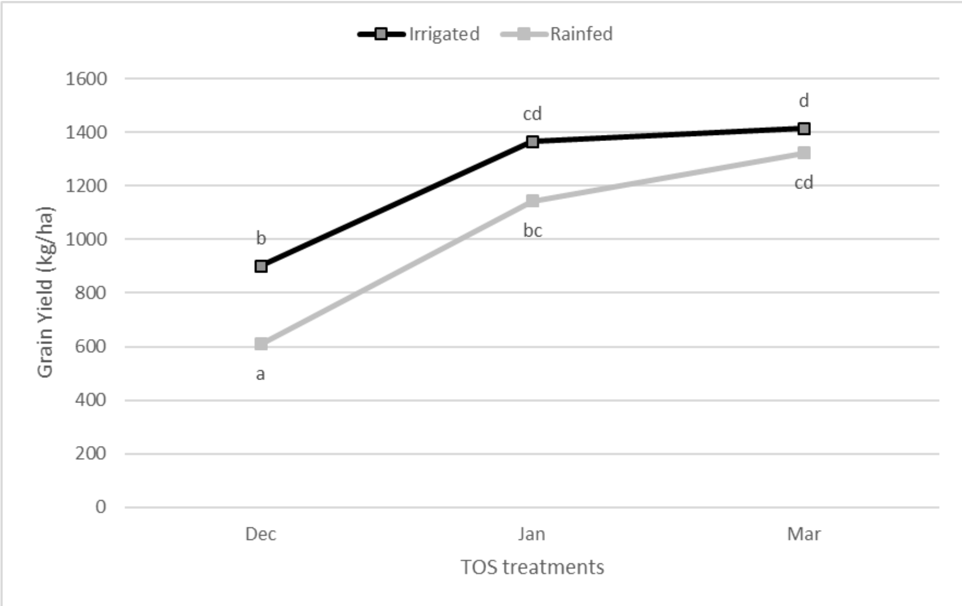

Figure 4. Comparison of mean grain yields for irrigated and rainfed treatments across three times of sowing (TOS). Means with the same letters are not significantly different at the P=5% level (LSD = 258.9).

Previous data sets from other TOS trials has shown that water balance in the plant is critical, especially the rate or speed that water has to be extracted (evaporative demand) and moved through the plant to maintain full turgor pressure in plant cells and maintain normal metabolism.

While temperature data and evaporation data can give good indications of when conditions are more extreme in relation to maintaining optimum plant growth, an alternative measure is vapour pressure deficit (VPD) which is a combination of temperature and humidity at the same moment in time. The drier the air the more pressure on the plant to lose water faster much the same way that delta T indicates the speed at which a water droplet will evaporate.

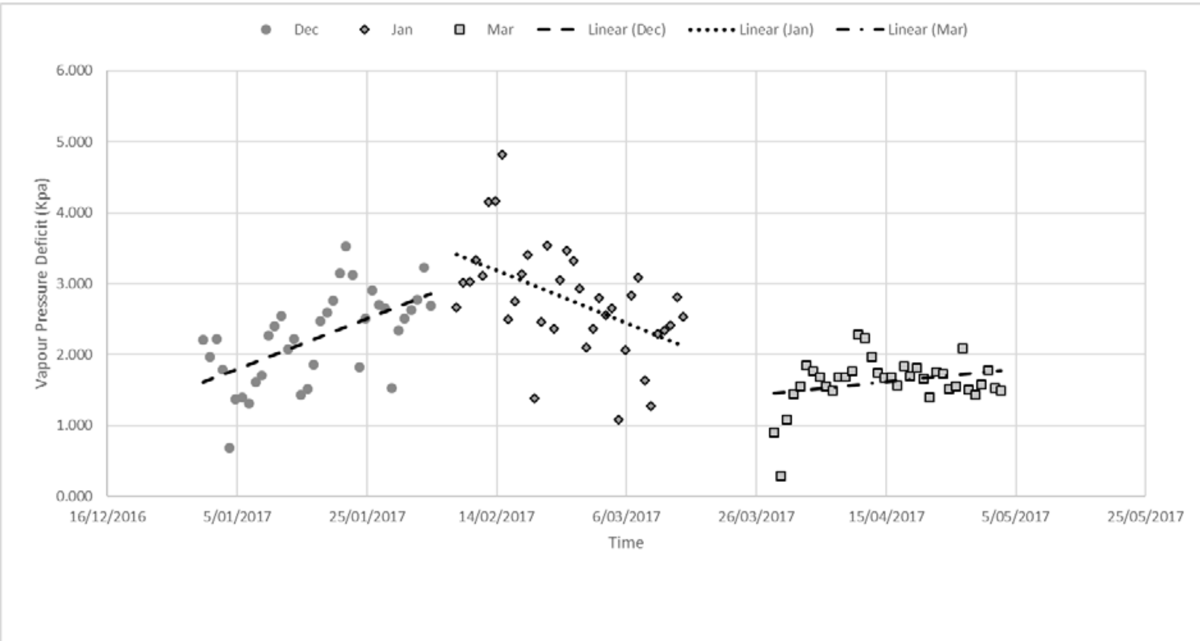

Figure 5. Mean daily Vapour Pressure Deficit (VPD) measurements for each time of sowing (TOS) over a five-week period centred on the start of flowering.

The VPD data for the 2017 trial (Figure 5) shows a contrast between all three TOS. The December TOS which had the lowest grain yield experienced increasing VPD from two weeks prior to the start of flowering and the three weeks that followed (most of the flowering period). The January TOS had almost the mirror image in terms of VPD readings with steadily declining numbers while the March planting had a more consistent readings which were mostly all under two kilopascals (Kpa).

It would be expected that these conditions would provoke a stress response of some sort in the plant itself. A symptom of this response may be evident in the pattern of dry matter accumulation in the plant particularly after the start of flowering.

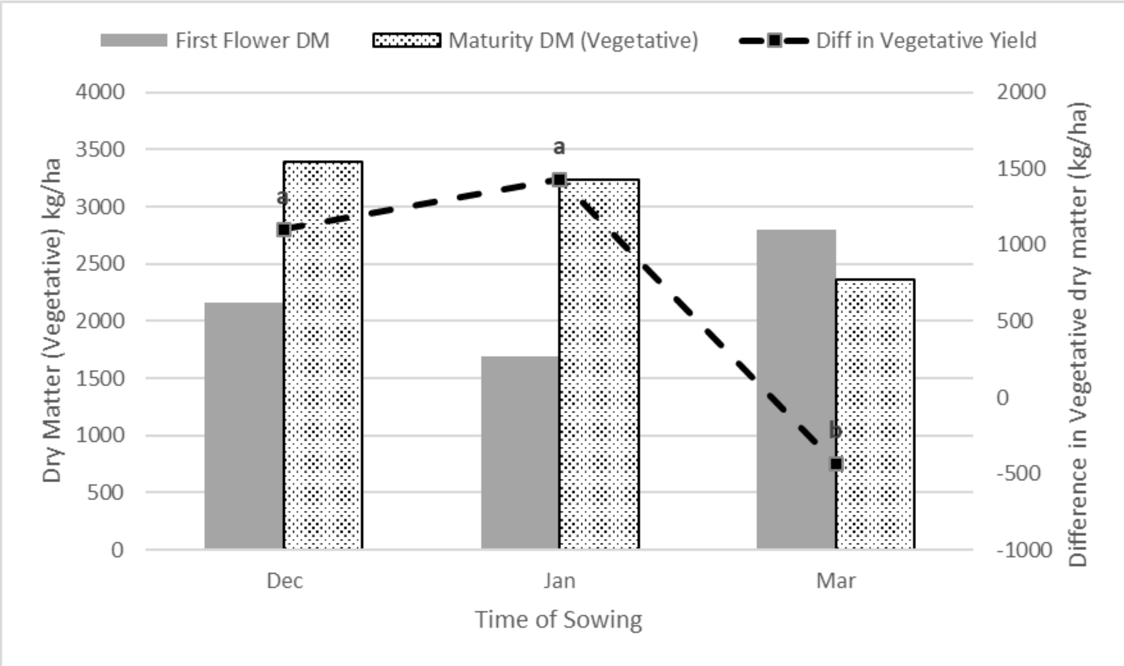

Figure 6. Difference in vegetative dry matter from the start of flowering to maturity across TOS. Means with the same letter are not significantly different at P=5% (LSD=415)

The two TOS that experience the highest levels of VPD, also produced the most amount of vegetative growth after the plant had started flowering (Figure 6). In contrast the March TOS grew no vegetative yield after flowering had started which is typically what the mungbean plant is physiologically programmed to do as it is classed as a vegetatively determinant plant. This means the December and January TOS were trying to grow vegetatively and reproductively at the same time which means a splitting of its resources at a critical time.

Consequently, the harvest index (total grain yield divided by total dry matter) of the first two TOS (Figure 7) were much lower than the March TOS of 0.33 – 0.35. This harvest index would suggest that yield potential was maximised in relation to vegetative growth for the March sowing whereas the other two TOS were not, despite growing more total dry matter (Figure 7). This may mean that plants growing in lower VPD conditions have the best chance of achieving their highest potential harvest index and consequently the most efficient grain yield.

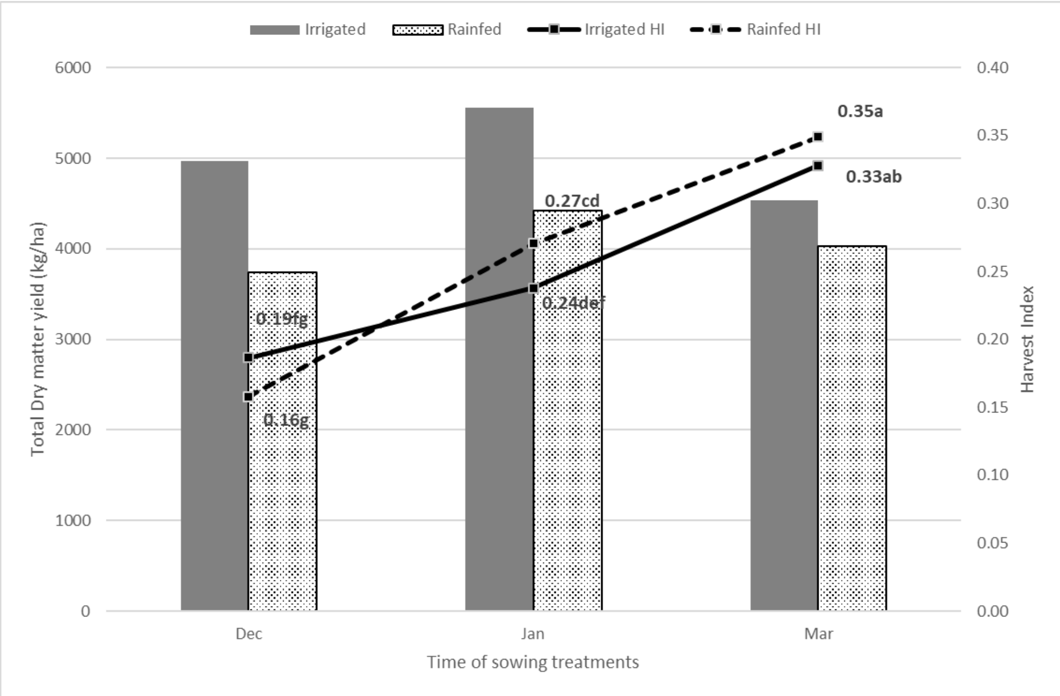

Figure 7. Comparison of total dry matter production and harvest index across TOS treatments split between irrigated and dryland conditions. Means with the same letters are not significantly different at the P=5% level (LSD=0.05247).

The consequence of this data is that plant windows should target weather conditions that give the plant its best chance of optimising its yield. Avoiding periods of high VPD conditions during flowering and the lead up to flowering could assist in maximising grain yield and harvest index for mungbeans. This experiment was conducted on the Central Highlands and clearly the later sowing had the benefit of avoiding those high VPD conditions; however, these conditions do not necessarily occur at the same time throughout the region nor do they occur at the same scale. For this reason, the optimum TOS maybe slightly different for each major growing region depending on when high VPD conditions are present and how severe they are. For example, there are subtle differences between the Central Highlands and the Dawson Callide growing areas in relation to VPD (Figure 8).

The Dululu site (Dawson Callide) shows VPD numbers dropping below 2.5 Kpa and staying below this figure from the 17 February onwards. For the Emerald site this does not occur until the 17 March (Figure 8). To ensure that the start of flowering occurs in these conditions; the sweet spot for planting should be no more than ~ 30 days earlier. Therefore, the most optimum planting window for Emerald is the 15 February (third week) and for the Dawson Callide it would be the 17 January (third week).

It is well understood that for dry land production systems planting opportunities will be based around the timing of rainfall so planting windows need to flexible; however the data in this paper makes the point that timing of weather conditions that contribute to a more optimum growing environment can change from region to region and can have a large benefit on yield.

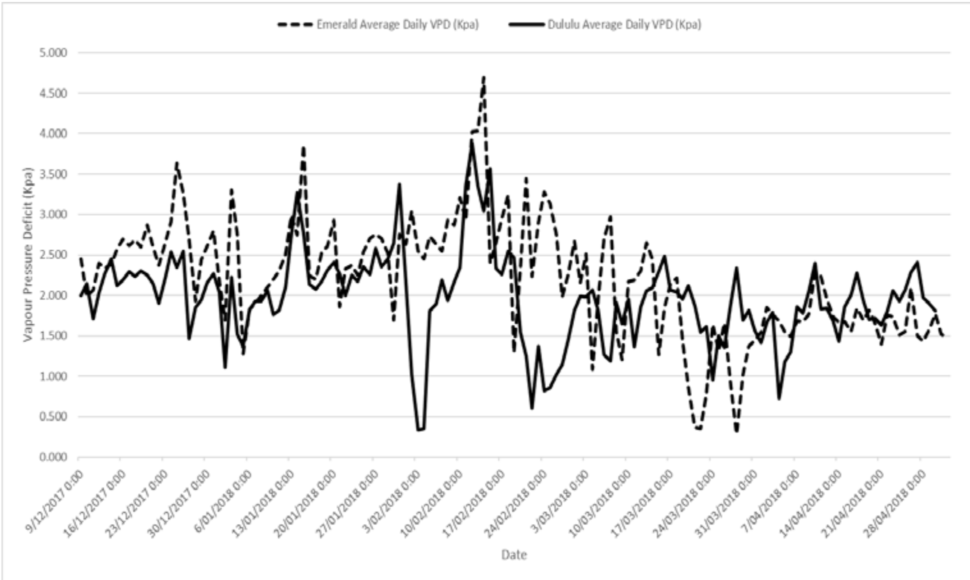

Figure 8. Daily mean VPD recorded for Emerald and Dululu in 2017-18 summer.

Summary

Row spacing configuration will only make an impact on grain yield for mungbeans when yields are approaching 1.5 t/ha or better and this tends to be where growers can use supplementary irrigation. Plant populations can be elastic as there is some compensatory capacity in the mungbean plant, however higher populations (35-45 plants/m²) can make a significant difference on narrow rows in high yielding situations (>1.5 t/ha). At the other end of the scale populations that are less than 10 plants/m² can have a significant decline in yield in both irrigated and dry land production.

TOS experiments have proven over a number of years that planting windows can have a big impact on yield. Poor production seems to be associated with conditions where the plant struggles to maintain its water balance on stored moisture, therefore those conditions that create high evaporative pressure on the plant seem to be the most limiting to yield.

One way of identifying these conditions is through the use of VPD data which takes into account not only temperature but humidity as well. When mean daily VPD figures are low (<2.5 Kpa) then the mungbean plant seems have a more normal growth pattern and subsequently a better harvest index. For growers in the CQ region using later summer planting windows (late January to early March) gives them the best chance of getting low VPD conditions before and during flowering.

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Making money from mungbeans – a growers perspective

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