BELLATA
NEW SOUTH WALES
FRIDAY 13
MARCH 2020

GRAINS RESEARCH UPDATE

DRIVING PROFIT THROUGH RESEARCH

GRDC™
GRAINS RESEARCH & DEVELOPMENT CORPORATION

Bellata War Memorial Hall

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GRDC 2020 Grains Research Update Welcome

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

Welcome.

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

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

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

Challenging seasons reinforce the importance of rigorous, innovative research that delivers genuine gains on-farm. For more than a quarter of a century the GRDC has been driving grains research capability and capacity with the understanding that high quality, effective RD&E is vital to the continued viability of the industry.

Sharing the results from this research is a key role of the annual Updates, which are the premier event on the northern grains industry calendar and bring together some of Australia's leading grains research scientists and expert consultants.

To ensure this research answers the most pressing profitability and productivity questions from the paddock, it is critical the GRDC is engaged with and listening to growers, agronomists and advisers.

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

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

Regards,
Gillian Meppem
Senior Regional Manager North

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GRDC Grains Research Update
BELLATA

Friday 13 March 2020

Bellata War Memorial Hall, Wilga St, Bellata

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

AGENDA		
Time	**Topic**	**Speaker(s)**
9:00 AM	**GRDC welcome**	
9:10 AM	**New technologies for the Australian grains industry** - Observations from a 4 month Fulbright Fellowship study tour of the USA and Germany	Craig Baille (USQ)
9:40 AM	**High yield wheat varieties with low lodging genetics in northern backgrounds**	Fernanda Dreccer (CSIRO)
10:10 AM	**Morning tea**	
10:40 AM	**N in the farming system** - the efficiency and positioning of applied fertiliser N; N use and export in pulse crops and implications for N application timing; where is our N and how much is there after the drought?	Jon Baird (NSW DPI) and Bede O'Mara (Incitec Pivot)
11:15 AM	**K nutrition** - what's new? Measuring, using and budgeting K. Sodium interactions, placement and payoff	Chris Guppy (UNE)
11:45 AM	**Cereal pathology after the drought** - evaluating risk after crop and pasture; what's new (seed treatments); Predicta® B for in-crop diagnostics; options for high risk paddocks; Ramularia	Steven Simpfendorfer (NSW DPI)
12:10 PM	**Lunch**	
1:10 PM	**Climate change in the northern NSW and strategies to adapt**	Steven Crimp (ANU)
1:40 PM	**Measuring soil water** - sensors and strategies - what works when and with what level of accuracy?	Jon Baird (NSW DPI), Drew Penberthy (Penagcon) and Brendan Griffiths (Precision Cropping Technologies)
2:10 PM	**Strategies for profitable decision making in 2020** - nutrition; soil water and sowing risk; varieties and time of sowing; weed management; disease threats	Discussion led by Drew Penberthy (Penagcon), Sam Simons (Poole Ag Consulting) and Jon Baird (NSW DPI)
3:00 PM	**Close**	

Contents

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New technologies for the Australian grains industry - observations from a 4 month Fulbright Fellowship study tour of the USA and Germany

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Notes

Better wheat germplasm for good seasons and high inputs

Fernanda Dreccer[1], Bethany Macdonald[2], Tony Condon[1], Greg Rebetzke[1], Lynne McIntyre[1], Valeria Paccapelo[2], Allan Peake[1] and Kerrie Forrest[3]

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Key words

wheat, high yield potential, lodging, irrigation, high nitrogen, phenotyping, pre-breeding

GRDC code

CSA00041

Take home messages

New wheat germplasm has been identified that lodges less than Australian cultivars EGA Gregory⦶, Suntop⦶ and LRPB Spitfire⦶.

From the favourable genetic markers identified in the new germplasm, only a proportion was present in a database of 502 Australian varieties, suggesting that there is room for improving lodging tolerance in high yielding wheats.

Background

Australian wheat breeding has been largely focused on improving crop yields for dryland environments. Wheat germplasm suited to higher-rainfall environments/years, irrigated systems and high fertility conditions is also needed, with high yield potential and reduced likelihood of lodging.

Lodging due to the permanent displacement of shoots from their upright position, is a common phenomenon in high yielding wheat crops. Lodging counteracts yield gains achieved by breeding and reduces the effectiveness of investment in inputs such as fertilisation and irrigation by reducing yield and quality. Yield is further reduced because fallen plants cannot intercept radiation fully to produce biomass. Direct losses can also occur due to shattering or at harvest, as low-lying spikes are not picked up by the header. The humid environment in a lodged crop can also affect bread-making quality due to higher incidence of pre-harvest sprouting and mycotoxin contamination (fungal infection) if ripening coincides with rainy, humid conditions. Finally, slow harvesting and the need for grain drying also represent additional costs for growers.

Lodging is a complex phenomenon, that depends not only on plant attributes but also soil type, how wet the soil is, wind and crop husbandry. Some of the popular management options, such as delaying N application, managing planting density and the use of plant growth regulators to lower plant height, have variable rates of success and substantial genotype x environment x management interaction (Peake et al., 2016).

Studying the impact of different management practices on lodging, researchers in the UK concluded that the best practice associated with high yields could not avert the damage of moderate to high wind speeds during grain filling, and new wheat genotypes were needed with increased lodging tolerance (Berry et al., 2000).

Two types of lodging have been documented, root or stem lodging. Hence any search for reliable plant traits has to phenotype attributes of the root plate (also known as crown root), the stem and the whole plant, such as height.

The north-eastern part of the Australian cropping belt, ranges from a subtropical climate with summer-dominant rainfall in the north towards a more uniform rainfall distribution in the temperate south. Typically, soils in this area have high clay content and high water-holding capacity. In this region, growers may have access to tactical irrigation around flowering to enhance grain yield. In good seasons or with supplementary water, if crops such as cotton precede wheat in the rotation, a high level of residual nitrogen in the soil is expected, adding to the environmental factors increasing lodging likelihood in crops expected to be high yielding. Occurrence of substantial yield losses due to lodging have been documented in this region for bread wheat and other crops. Hence the need to find better genetic backgrounds for the varieties available for growers.

The overall aim of this project was to provide Australian breeding companies with access to regionally adapted germplasm with stable yields higher than 7 t/ha, with low lodging and deliver information on how to select for low lodging, high yielding wheats, in the form of knowledge about the key traits, phenotypic selection tools and DNA markers.

Methods

The first step was to assemble a highly diverse set of materials, such as local varieties, advanced breeding lines and imported germplasm and identify those that consistently delivered low lodging and high yield across the northern region. Nineteen multi-environment experiments were run over four years in Emerald and Gatton (QLD), Narrabri and Spring Ridge (NSW). The experiments were fertilised with high N doses before sowing (300-350 kgN/ha) and tactical irrigation was used after flowering to induce lodging. Each plot was assessed for yield, height, flowering and percentage of the crop lodged at which angle, border rows were excluded. With the combination of angle and percentage lodged, we built a 'lodging score'. A lodging score of 0=not lodged and 100=completely lodged (flat on the ground). The benchmark lodging score for the project was 80% of the crop leaning 20° from the vertical and the rest standing, equivalent to '17.8' in terms of lodging score.

A selection of 50 lines was further characterised in detailed phenotyping field experiments for 20-plus traits, mainly attributes related to either root or stem lodging, i.e. root plate spread (RPS), and structural rooting depth, stem strength, diameter and thickness, and components of shoot leverage, such as plant height and height at the centre of gravity.

From the phenotypic characterisation, four donors were selected and were crossed to three recurrent parents chosen by the Australian Plant Breeders Reference Committee – these being EGA Gregory⦶, Suntop⦶ and LRPB Spitfire⦶. Flowering, height and lodging were scored for two consecutive years in the twelve populations; yield data are available for one year only. 288 EGA Gregory⦶ derived and 63 Suntop⦶ derived lines were genotyped using a 90K Single Nucleotide Polymorphism (SNP) platform. This genetic information was associated with lodging scores from the field to detect relevant DNA markers.

Results and discussion

Extensive field phenotyping using high N fertility and tactical irrigation led to a range of yield and lodging outcomes in multi-environment experiments (Table 1) and highly reproducible rankings for lodging (Figure 1). This means breeders can treat the region as a single target.

Table 1. Mean and range of yield and lodging observed in multi-environment experiments

Year	Locations	Genotype #	Yield (t/ha)		Lodging score	
			Mean	Range	Mean	Range
2012	Emerald	40	5.9	5.2-7.2	-	-
	Gatton	308	5.4	3.4-7.3	39.7	4.3-74.8
2013	Emerald	50	6.7	4.4-8.2	8.2	0.0-28.2
	Gatton	240	4.9	3.0-7.3	12.4	0.6-29.6
	Narrabri	240	6.2	4.0-9.2	5.8	0.0-28.2
	Spring Ridge	50	7.8	6.9-8.6	-	-
2014	Emerald	50	6.0	4.9-7.3	14.2	4.8-23.9
	Gatton	120	5.9	3.6-7.8	11.7	0.0-35.2
	Narrabri	240	6.9	4.6-10.1	16.4	0.0-38.5
	Spring Ridge	51	7.8	4.6-10.2	29.9	1.0-71.6
2015	Emerald	50	7.8	5.5-9.6	8.3	2.2-19.2
	Gatton	50	6.0	4.7-7.7	8.2	0.0-50.4
	Narrabri	50	9.1	7.0-10.3	16.3	1.5-55.9
	Spring Ridge	50	10.0	7.1-11.9	15.8	0.0-70.0
2016	Gatton	51	6.8	4.8-8.4	59.6	12.2-90.2
	Narrabri	54	8.1	6.5-9.6	19.8	0.0-53.1
	Spring Ridge	51	9.6	7.3-10.9	18.8	0.0-67.7

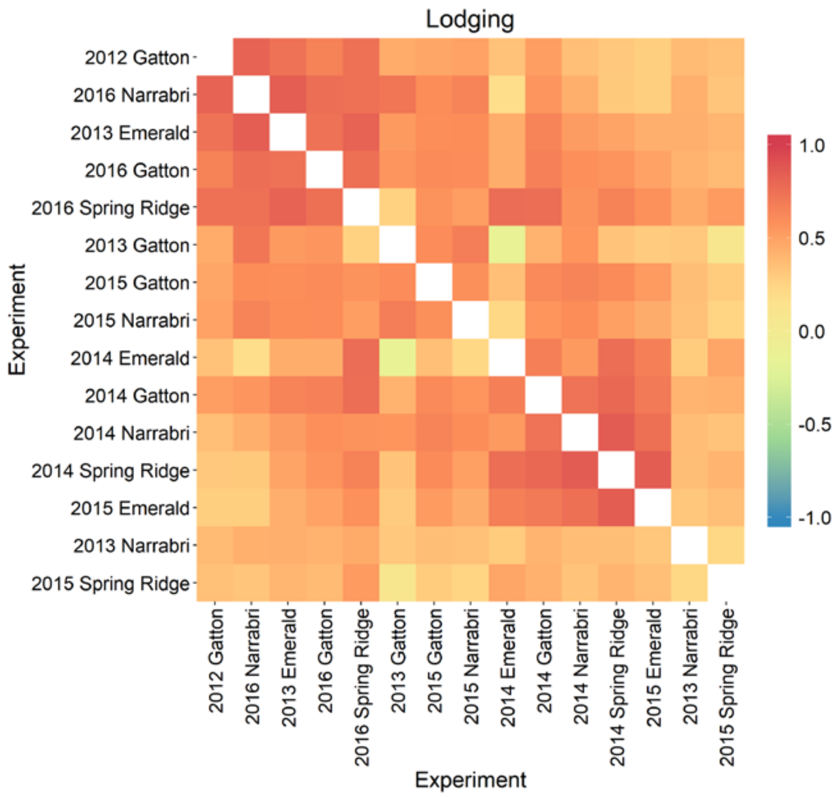

Figure 1. Genotypic correlation matrix for lodging scores between experiments. Scale for genotypic correlation is given as a colour shading denoted in the colour panel at right. A value of 1 indicates a positive and perfect correlation between experiments, i.e. they rank varieties similarly for lodging scores

A selection of fifty lines underwent a detailed field phenotypic characterisation over two years. Field grown plants were ‘pulled-up’, root plates washed and measured as shown in Figure 2. Root plate spread emerged consistently as a trait able to discriminate low lodging, high yielding germplasm in a classification analysis with a regression tree (Figure 3). If the root plate spread was greater than or equal to 5.5 cm, the lodging scores were small, and yield was high. Stem breaking strength (far right in Figure 2) emerged as an important trait for genotypes with narrower root plates (less than 5.5 cm). Figure 3 shows the regression tree illustrating how trait levels separate groups or nodes of data.

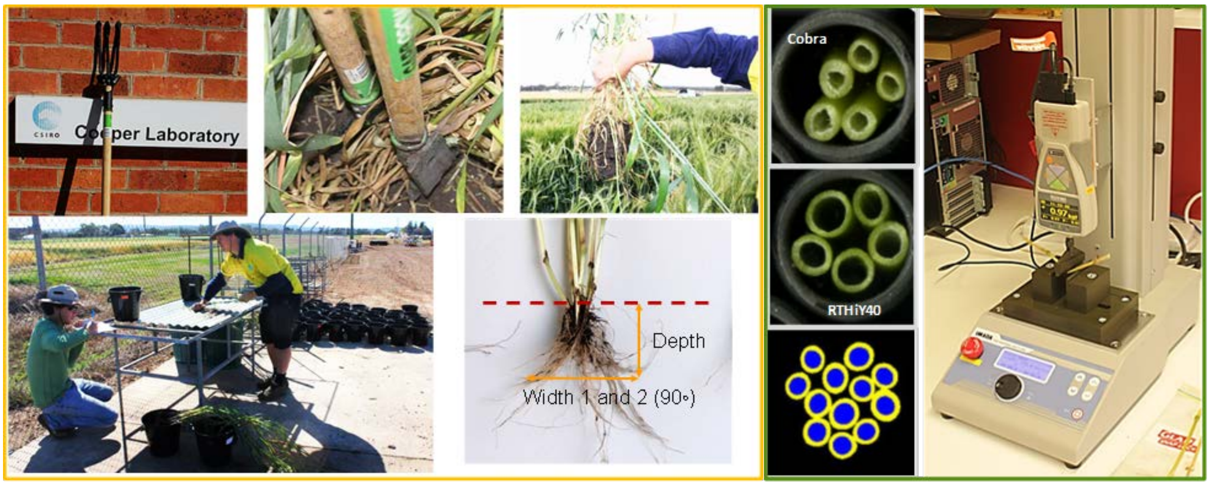

Figure 2. Photos of root sampling, stem breaking and imaging. Images courtesy of Ryan Kearns, Ian Lee Long and Fernanda Dreccer (CSIRO)

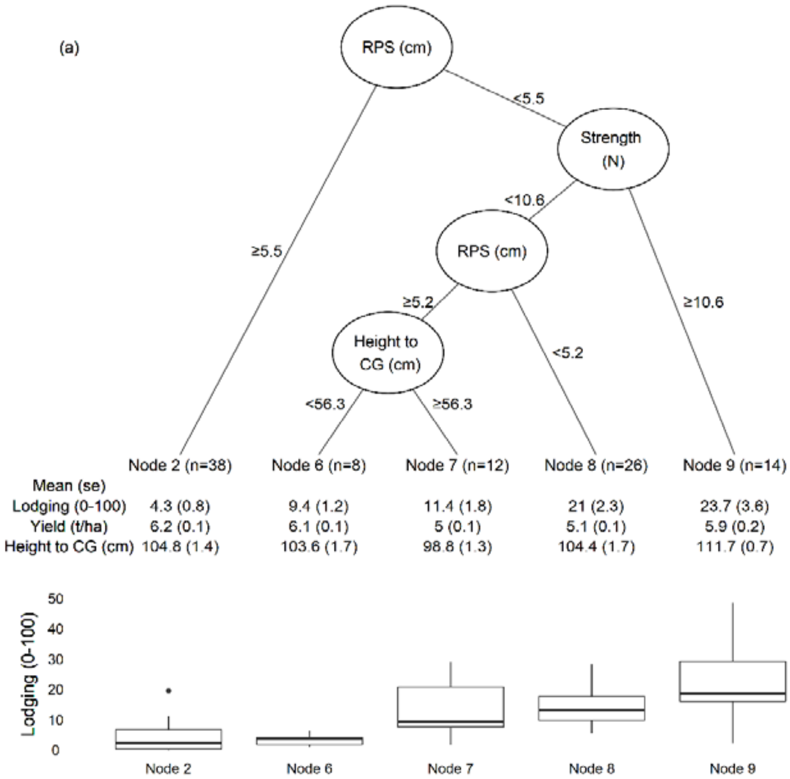

Figure 3. Regression tree. ‘RPS’, root plate spread (cm); ‘strength’, stem breaking strength (N), ‘height to CG’ height to the centre of gravity. Mean and standard error for lodging, yield and height to the centre of gravity indicated below the bubbles. “n” is the number of data in each node. Lodging boxplots for each node shown below

From this phenotypic characterisation, four donors were selected, one an Australian cultivar (LRPB Cobra⑰), the other three exotic lines from CIMMYT (RTHiY40, RTHi32, RTHiY57). Donors were low lodging, high yielding, contrasting in height and generally showing wider root plate spread (belonging to Node 2 in Figure 3) than the Australian cultivars parents of the new populations. It is possible that the importance of anchorage characteristics for our conditions is related to the high clay content of the soils in the northern region, typically above 35% clay from the surface (https://aclep.csiro.au/aclep/soilandlandscapegrid/ViewData-QuickView.html) that, when wet, create a very unstable environment for crops to anchor.

Lodging was first evaluated for the new populations in single rows, bordered by the same cultivar to avoid bias. EGA Gregory⑰ derived lines lodged in a higher proportion and with a higher deviation from the vertical. More than 50% of the EGA Gregory⑰ derived lines lodged less than EGA Gregory⑰, with the tallest donor, RTHiY40 (ca. 107 cm), producing lines as effective as those derived from the shortest donor, LRPB Cobra⑰ (80 cm), in both years. In our experiments, lodging and height were not associated.

Yield was measured in 2018 only in the lodging nursery after heavy rain and ranged from 570 g/m^2 (5700 kg/ha) to 761 g/m^2. Among the EGA Gregory⑰ populations, 100 lines had a lodging score significantly below the 17.8 benchmark in that year, 12 of which yielded as much as or more than EGA Gregory⑰. When LRPB Spitfire⑰ was the recurrent parent, the lines derived from crosses to LRPB Cobra⑰ and RTHiY57 were best at reducing lodging.

DNA markers for lodging were detected both in a biparental population from CIMMYT (Seri x Babax) and the lines from the new populations that were genotyped. These genetic markers do not coincide with known flowering or height genes. Interestingly, the DNA markers that come up in a year of low lodging are dissimilar to those observed in a high lodging year, suggesting that the plant attributes that are important vary with the level of lodging. In 2017, a high lodging year, 4 significant DNA markers were detected for lodging scores. If present in their favourable form, they can reduce the lodging score by approx. 8 points each.

A search for the favourable DNA markers found in the new populations in 502 Australian varieties with known genetic profiles, indicated that no single Australian variety has all the favourable genetic markers. Lodging predictions were generated for the 502 varieties based on the DNA markers detected based on their genetic profile in a high and low lodging year. Amery and Stockade were the only two varieties consistently among the top 25 with lowest predicted lodging score (Figure 4). Further analyses will be carried out in this area to pass the information of the best candidate markers to breeders.

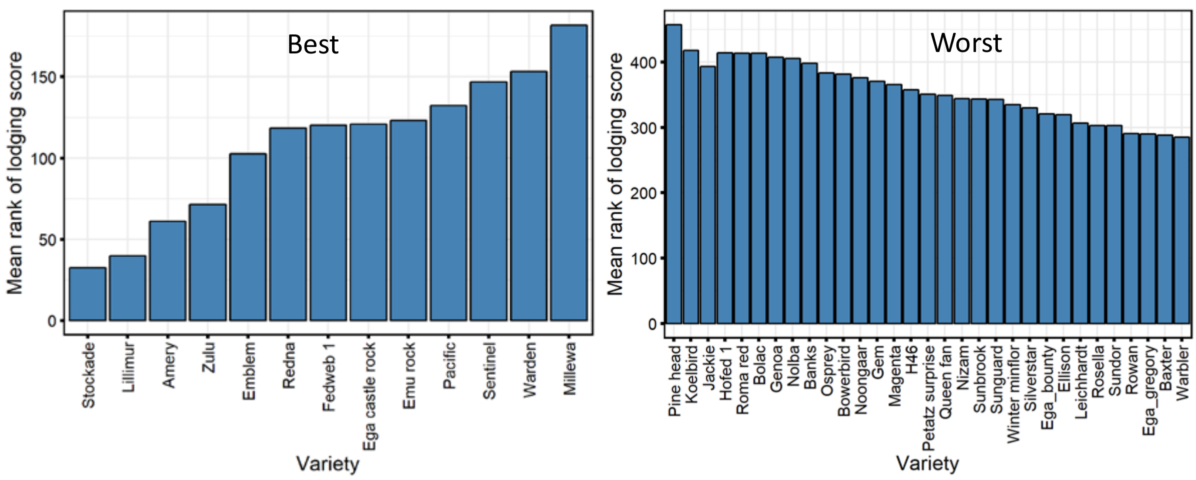

Figure 4. Varieties which have a mean rank of predicted lodging score which falls in the top 25 or the bottom 25 in at least two analyses

Conclusions

This project succeeded at finding genetic diversity for lodging in high yielding wheats and transferring it to new germplasm with known varieties as background. Many of these lines lodge less than their parents and some yield more. The process of selection and investigation of relevant plant attributes succeeded at detecting the traits that were more important to choose donors for our target region, firstly root anchorage, then stem strength.

The findings of this project may not only be beneficial for the northern region but could spill over to wheat varieties designed for the high rainfall zone in the South and high yielding environments of Tasmania or Northern Australia. In addition, the general approach to selection and characterisation of plant attributes is a framework that could be extended to other crops.

Furthermore, as not all favourable genetic markers found in the new populations were present in Australian varieties, there is room to improve lodging tolerance in Australian breeding.

References

Berry, P.M. et al., 2000. Controlling plant form through husbandry to minimise lodging in wheat. Field Crop. Res., 67(1): 59-81.

Peake, A.S., Bell, K.L., Carberry, P.S., Poole, N. and Raine, S.R., 2016. Vegetative nitrogen stress decreases lodging risk and increases yield of irrigated spring wheat in the subtropics. Crop Pasture Sci., 67(9): 907-920.

Acknowledgements

The research undertaken as part of this project was made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC and the cooperation of Australian Plant Breeders. The authors would like to thank them for their continued support.

The technical expertise of Allan Peake, Claire Farnsworth, Mary Anne Awasi, Andy Hundt and Ian Lee Long (CSIRO) is greatly appreciated.

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

Nitrogen in the farming system: drought implications on the availability of nitrogen. How much is there and where is it within the profile? Does cropping sequence influence fallow mineralisation activity?

Jon Baird[1], Jayne Gentry[2], David Lawrence[2], Andrew Erbacher[2], Darren Aisthorpe[2], Lindsay Bell[3], Brook Anderson[3], Greg Brook[1], Andrew Verrell[1], Mathew Dunn[1] and Bede O'Mara[4] (Incitec Pivot Fertilisers)

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[4] Incitec Pivot Fertilisers

Key words

nitrogen, northern farming systems, rotations, pulses, nutrient removal, soil testing, NUE, fertiliser placement, profile position

GRDC code

DAQ00192, CSA00050

Take home messages

- Test your soils! It is imperative that growers know the soil nutrient balance and beneficial fungi numbers before they enter back into a cropping system. Some interesting trends that we have found from our research include:

  - Even during low and periodic rain periods, mineral nitrogen levels may have increased greatly during the drought - especially during the warmer summer months

  - There was minimal to no mineralisation activity during the dry winter months (April-September at Narrabri 2018)

  - When research sites did receive isolated rain during the winter months, mineralisation activity was still low but there was a movement of nitrate down the soil profile to where the next crop will use it

- This paper has focused on Nitrogen (N), but growers should also be aware of the dynamics of other key nutrient and beneficial fungi numbers. Data not included in this paper suggests that mycorrhizae fungi (AMF) decreased considerably during the drought, to where the next crop may be impacted if they are susceptible to the long fallow disorder

- Cropping sequence influenced mineralisation activity in the subsequent fallows. This research showed that growing legumes may not boost mineralisation activity, but crops with high dry matter production (such as canola) had greater mineralisation activity in the following fallow periods.

Introduction

The ongoing drought conditions in the northern grains region (NGR) has influenced the nitrogen dynamics of our cropping systems. The enforced long fallows and failed crops have reduced plant vegetative production, resulting in lower organic matter production and a significant reduction of residual stubble cover.

When a future planting opportunity presents itself, to ensure cropping systems continue to produce high grain yields, growers will need to be mindful of the fertility status of their cropping soils. This should be done on a paddock by paddock basis. The extended long fallow and lack of productivity may have nutritional implications for key plant nutrients (N & P) and beneficial fungi numbers within the soils of the NGR.

This paper will outline long-term soil nutrition results from the GRDC, NSW DPI, DAF and CSIRO funded Northern Farming Systems Initiative, and also data collected by the long-term nutrition trials managed by Incitec Pivot. Results have been extracted that specifically relate to the long fallow and current drought conditions experience throughout the NGR and how these differ across various farming systems.

Methodology

In 2014 the Northern Farming Systems Initiative implemented long-term farming systems research at seven sites throughout Queensland and northern New South Wales. A baseline cropping system, representing commercial best practice, was established at each site and tested against systems with higher and lower crop intensity, higher crop diversity, greater use of legumes and higher fertiliser inputs. Parameters including soil water, nitrogen and soil pathogens were regularly monitored along with crop biomass, grain yield and variable costs for each crop as measures of system performance.

This paper will interrogate data from the Narrabri research site (University of Sydney research farm "Llara" and the Pampas site (located 45 minutes south of Toowoomba).

Experimental procedures for the Northern Farming System project included measuring mineral nitrogen (nitrate and ammonium), both pre-sowing and post-harvest for each crop planted over the past four years. Grain content was also analysed for nitrogen (N), phosphorus (P) and potassium (K). Exported nutrients were calculated using grain nutrient content and dry weight grain yield.

The Incitec Pivot research was located at three Darling Downs sites, which were monitored for extensive time periods, measuring nitrogen (nitrate, ammonium and total N%), along with sulphur (MCP & KCl) and soil chloride (S & Cl not presented here). Whilst the initial intent was for samples to be taken monthly, in reality they have been taken irregularly in the months indicated in the figures and graphs below (i.e. not strictly 30 days apart) from pegged plots nominated by growers as representative of their paddock.

Segmented profile samples using the Fertcare soil sampling guidelines (Gourlay & Weaver, 2019) of 0-10 cm; 10-30 cm; 30-60 cm; 60-90 cm and 90-120 cm were collected.

Care is taken at each sampling date to ensure consistent soil core position (i.e. same tramline and wheel track), adjacent to previous core holes and in the same configuration amongst rows and other unique artefacts at each site.

Research site descriptions

Northern Farming Systems Initiative

- Narrabri - The soil at the site is a brown-grey Vertosol with medium-heavy clay throughout the soil profile. The plant available water holding capacity calculated at the site is 190 mm for wheat to a depth of 120 cm, it is likely additional water may be available at deeper depths in this soil, although the site contains high sodicity (ESP >10) at depths below 60 cm. The various research cropping systems are designed in a randomised layout with 4 replications
- Pampas - The soil at the site is a deep black Vertosol with medium-heavy clay throughout the soil profile. There is a graduation from black to brown clay at 1.2-1.7 m at the site, with this occurring at shallower depths at the lower elevation. The site has high background

fertility levels and no subsoil constraints. The plant available water holding capacity calculated at the site is 240 mm for wheat to a depth of 150 cm, but it is likely additional water may be available at deeper depths in this soil.

Incitec Pivot Darling Downs sites (commercial paddocks)

Dalby, Qld - Light Brigalow clay soil, CEC 37 cmol(+)/kg, with moderate subsoil chloride (~1,000mg/kg) at >90cm depth. No nitrogen fertiliser was applied to this site since the 2015 wheat crop. A bare fallow plot (uncropped for the duration of sampling) has been compared to an adjacent recently cropped plot area.

- Dalby site A: Fallow: long bare fallow plot 12 m x 12 m ex chickpea 2016. Very low soil cover. Sampling commenced on 2/1/2018
- Dalby site B: Crop: plot 12 m x 12 m grain sorghum planted 1 Dec 2018 and harvested April 2019. Yield 3.4 t/ha, with approximately 60 kg N/ha exported within the grain.

Pampas, Qld - Heavy grey/black clay, CEC 55 cmol(+)/kg with no apparent subsoil constraints. Adjacent plots to monitor the fate of fertiliser N applied vs nil applied

- Pampas NW site: long fallow plot 12 m x 12 m ex grain sorghum 2016/17. Sampling commenced 16/4/2018
- Pampas SE site: long fallow plot 12m x 12m ex grain sorghum 2016/17. Sampling commenced 16/4/2018. 92kgN/ha (200kg urea/ha) (single disc machine) applied 20/6/18.

Mt Irving, Qld - Heavy grey clay, CEC 48 cmol(+)/kg with no apparent subsoil constraints. Sampling commenced on 12/2/2018. Single plot 12 m x 24 m. Ex wheat 2017; 107 kg N/ha as 130 kg/ha BIG N® applied in July 2018 using single disc machine, long fallowed into corn 2018/19 planted on 16/10/2018 and salvaged as silage yielding 11.6 t/ha (wet weight) green chop in January 2019. Following this harvest, 60 kg N as 73 kg/ha BIG N® was applied in April 2019 using a single disc machine.

Results

Drought impact on mineral N in northern cropping systems

The past 18 months in the northern grains region had received lower than average rainfall and above average temperatures. For growers who have been forced into long fallows scenarios due to these drought conditions, there has been a significant change to the mineral N dynamics within their cropping soils. The high temperatures during the summer months provided a basis for high rates of mineralisation activity especially within the vertosols soils that had adequate levels of organic matter. For regions that did not receive a significant storm event or isolated rain, the high mineralisation increased mineral N levels to extremely high amounts.

For example, at the Narrabri farming systems site, two cropping systems (*Higher Diversity and Lower Intensity)* were in fallow since December 2017. During the long fallow period, the cropping systems have increased nitrate N levels from 20 kg N/ha to over 90 kg N/ha (Figure 1). A closer look at the fallow period showed that the cooler 2018 winter months had little to no mineralisation activity at Narrabri, while the warmer summer fallow of 2018-19 provided the greatest increase in nitrate N levels during the 18 month drought period. Although the 2018/19 summer received below average rainfall and above average temperatures, the site did have high mineralisation activity. The lack of plant N uptake allowed for the mineralised N to accumulate during this period.

These results show that the process of mineralisation (where the organic or inorganic matter is converted by microorganisms into plant available N) can occur at low to moderate soil water content and low rainfall periods. Figure 1 shows the decline in monthly rainfall after the 2017 winter at Narrabri. As the systems entered the fallow (2017-18 summer), there was no significant rainfall event during the next two years. Soil moisture during this period remained approximately 40-50% of PAWC (60-80 mm).

In contrast, if during the long fallow, cropping systems received an isolated rainfall event, the mineral N within the soils may decrease due to losses from denitrification. Denitrification – N losses due to the emissions of N_2 – occurs when soils have high nitrate concentration and become saturated with moisture. When the soils' dry down from peak saturation, nitrogen is lost in gaseous form. The Incitec Pivot site at Dalby received isolated storm events during the month of December 2018. During these months the Dalby site lost mineral nitrogen in the form of nitrate from the peak of 441 kg nitrate N/ha in November 2018 down to 283 kg nitrate N/ha in April 2019 (Figure 2).

Although soil nitrate N levels have increased during the dry drought conditions, one issue that could hamper growers leading back into a cropping sequence is that soil mycorrhizae (AMF) has decreased to alarmingly low levels (data not presented in this paper). Levels are now within the high risk range for susceptible crops for the long-fallow disorder, so growers need to be mindful of their mycorrhizae fungi levels when selecting their first crop after the long fallow period.

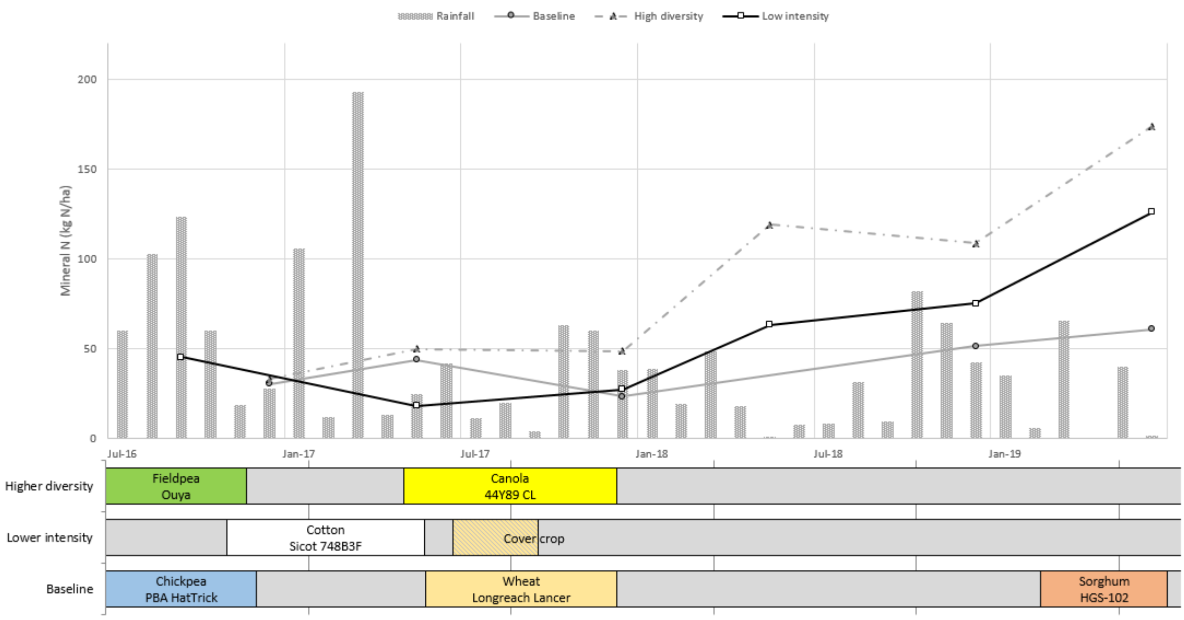


Figure 1. Long term soil mineral N (kg N/ha) levels and monthly rainfall (mm) at the Narrabri farming systems research site (2016-2019)

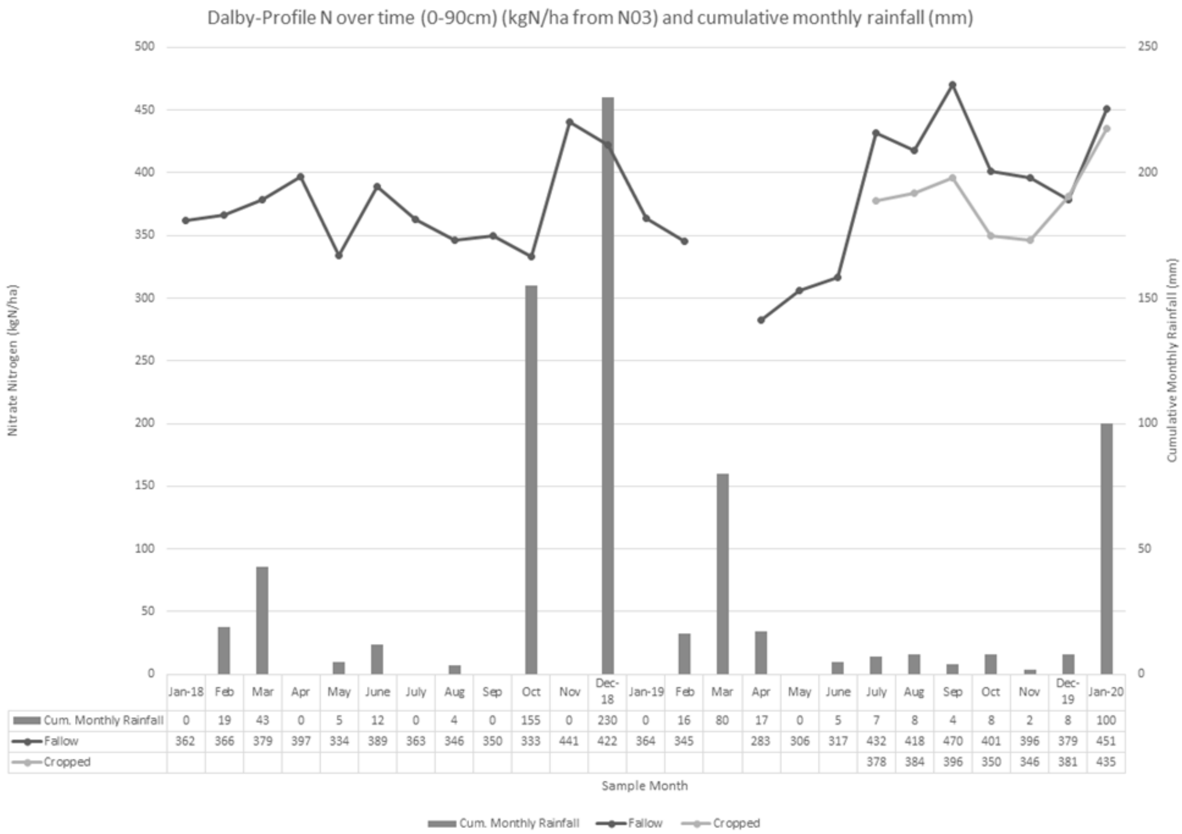


Figure 2. Measured nitrogen values in the 0-90cm profile taken from segmented profile samples and cumulative monthly rainfall (mm) from January 2018 until January 2020 at Dalby, Qld

Where is my nitrogen after the drought?

When studying the available mineral N during the long fallow period, we found after the initial increase of mineralised N in the top soil, there was a definite movement of mineral N down through the soil profile especially for cropping systems dominated by winter crops (Narrabri and Pampas-winter). For instance, the summer season of 2017/18 saw significant levels of mineralisation within the 0-15cm depth at the two Northern Farming Systems sites (Figure 3). This corresponds with the location of microbes responsible for the breakdown of organic matter into the plant available form of nitrate and ammonium. Sampling after the winter of 2017 found that the mineral N that mineralised during the previous summer, had filtered down the profile into the lower depths (30-60 cm). This pattern continued during the last phase of the fallow as the accumulated mineral N increased in the 60-90 cm depth. These results show that in soils that have been accumulating mineral N during recent dry fallow periods, the mineral N continues to move through the soil profile during cooler months and periodic rainfall events. This is important for the next phase of the cropping sequence, as now it can be assumed that not only do we have ample mineral N available to produce grain yields, but the location of the N is within the soil layers where plants require peak N uptake during key growth stages.

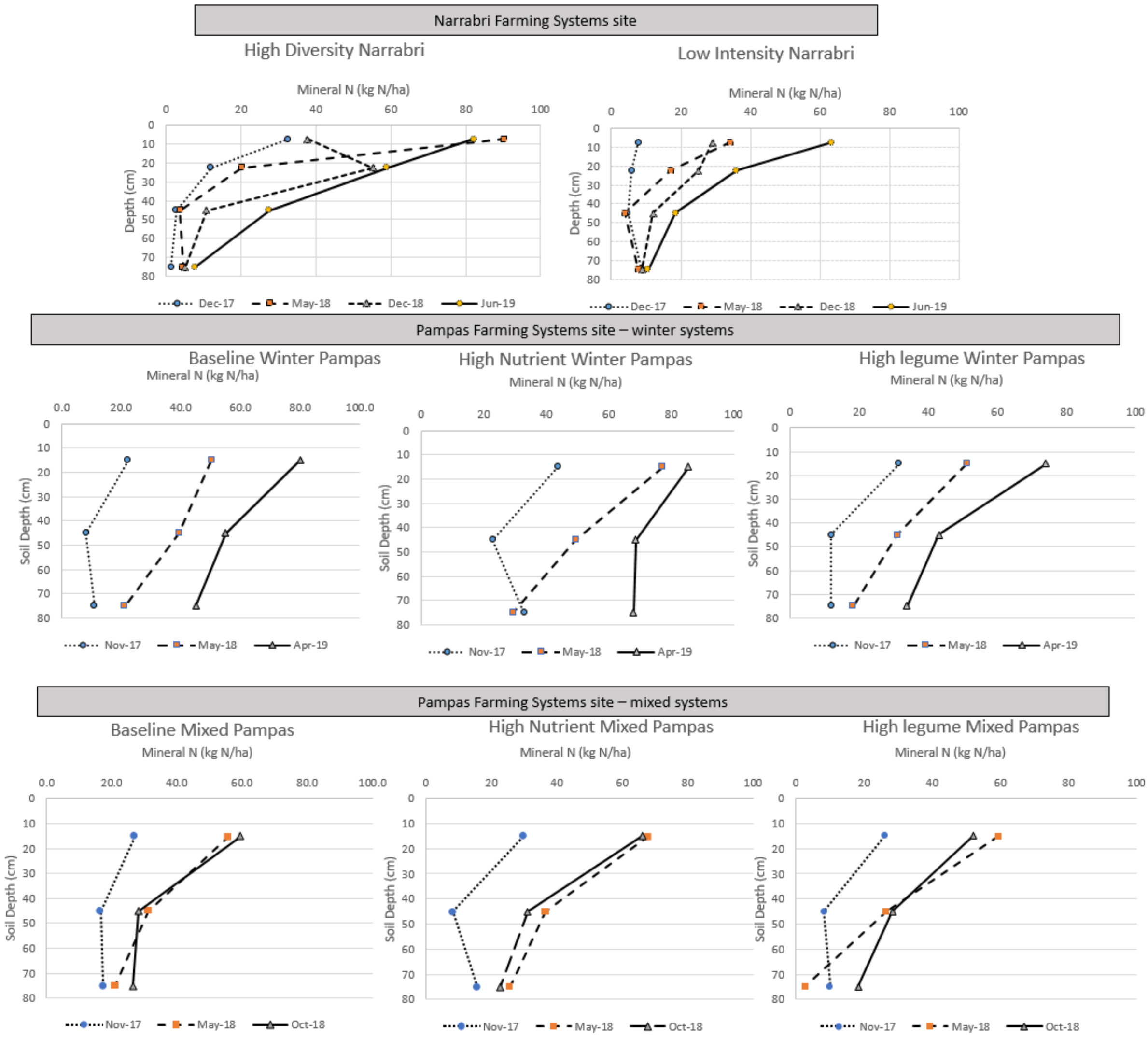


Figure 3. Distribution of mineral N placement within the soil profile over a long fallow period at Narrabri and Pampas farming systems sites (December 2017 – June 2019)

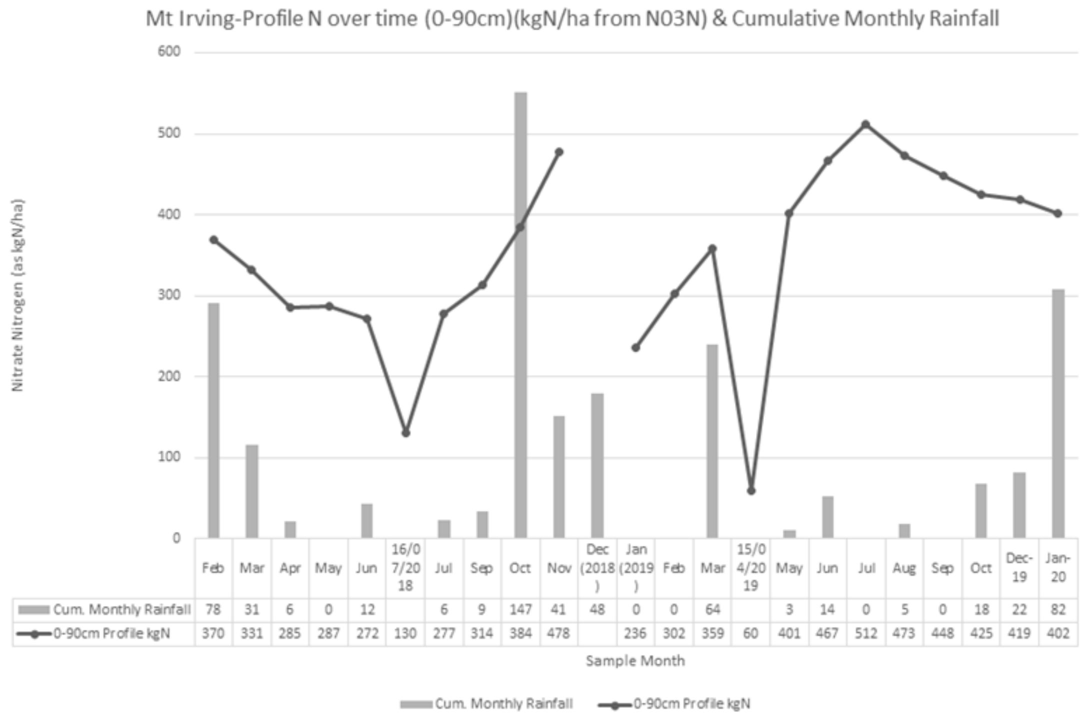
What happened to my N fertiliser if I applied it a while ago (or earlier in the drought)?

N application decisions or practices are driven by a series of factors, including agronomic or practical farm calendar timing, N price, soil moisture, other farm enterprise or business demand such as labour availability. In preparation for cropping, growers may have applied nitrogen fertiliser to their fields quite some time ago before the drought forced them into a long fallow. This practice involves a level of risk (pre-plant N losses or recovery in future crops) and compromise (timing, soil conditions may not be ideal).

Is my N still there?

Studies at the Mt Irving Incitec Pivot paddock site show that with soil moisture approximated at 50% of PAWC, the applied nitrogen fertiliser (as Anhydrous ammonia – BIG N) in July 2018 took approximately four months to become converted into nitrate N (Figure 4). In addition to soil moisture, temperature influences the nitrification rate of fertiliser and soil N, and the apparent slow nitrification can be attributed to both soil moisture and soil temperature. Prior to N fertiliser application (April to July 2018), nitrate N equalled 384 kg N/ha (0-90 cm soil depth), however, after the fertiliser had fully nitrified into nitrate nitrogen, culminating in the 0-90cm profile N level of 478 kg N/ha being present in November 2018. It is assumed that whilst the soil moisture profile was stable from April to October 2018, it was the October rainfall (147mm) that likely completed the nitrification of the applied fertiliser and likely provided additional mineralised N to further bolster soil test N values.

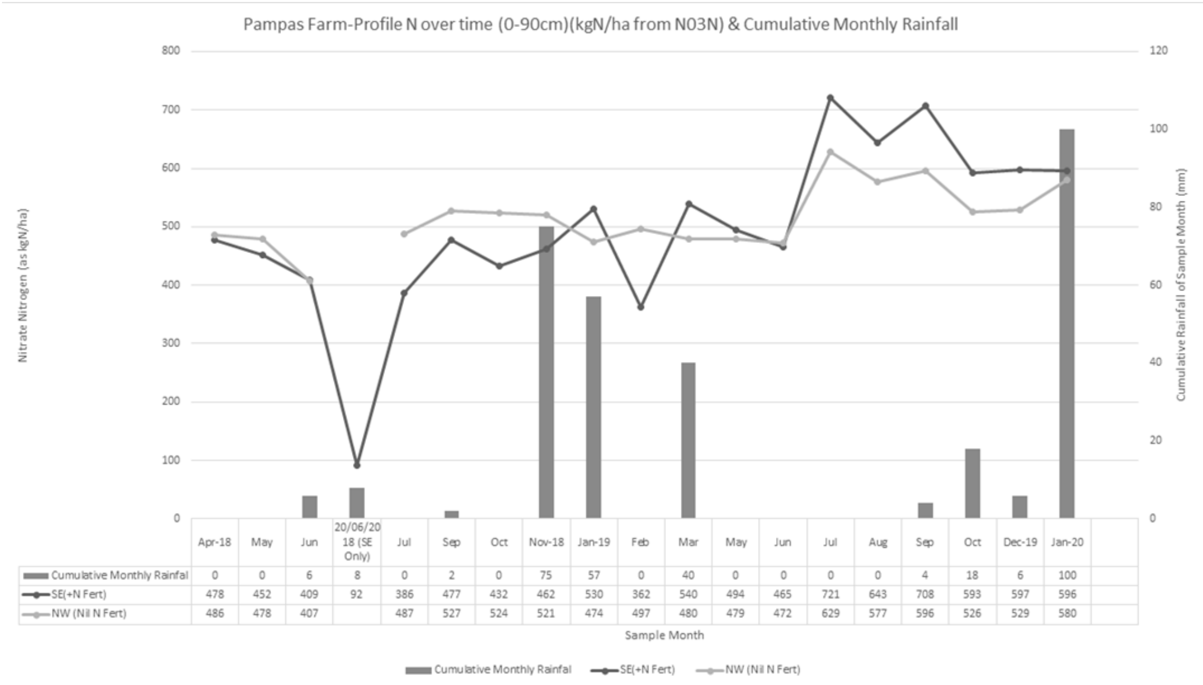
The January 2019 soil sample timing coincides with the commencement of the fallow following the corn silage crop being removed. From nutrient samples collected at silage harvest, 105 kg N/ha (+9.5 kg P; 89 kg K; 5.8 kg S & 185 g Zn per hectare) was removed by this crop. It is assumed that the February and March 2019 soil N increases are from the Feb/Mar rainfalls when 56mm was received. With little effective rainfall (frequency or quantity) in events since, the latest soil sampling data (December 2019) provides logical extension that the April 2019-applied BIG N and subsequent mineralisation and nitrification has resulted in a plausible soil test N value being present.



	Feb	Mar	Apr	May	Jun	16/07/2018	Jul	Sep	Oct	Nov	Dec (2018)	Jan (2019)	Feb	Mar	15/04/2019	May	Jun	Jul	Aug	Sep	Oct	Dec-19	Jan-20
Cum. Monthly Rainfall	78	31	6	0	12		6	9	147	41	48	0	0	64		3	14	0	5	0	18	22	82
0-90cm Profile kgN	370	331	285	287	272	130	277	314	384	478		236	302	359	60	401	467	512	473	448	425	419	402

Figure 4. Incitec Pivot site 'Mt Irving' soil sampling profile N data (The 16/7/18 and 15/4/19 data callout boxes indicate the NH3 BIG N application rates by the grower) and cumulative monthly rainfall (mm)

The Incitec Pivot Pampas Qld site had nitrogen applied in a long fallow back in June 2018, in readiness for a 2018-19 summer crop. The 92 kg N/ha application treatment (urea @ 200 kg/ha) had approximately 400 kg N/ha present in the 0-90 cm profile at that time. Due to very low rainfall and no crop removal event since, 74% of the applied N and N present prior to fertilising is accountable as the difference between the fertilised (597 kg N/ha) compared to 529 kg N/ha present in the unfertilised as at December 2019 (Figure 5).



	Apr-18	May	Jun	20/06/2018 (SE Only)	Jul	Sep	Oct	Nov-18	Jan-19	Feb	Mar	May	Jun	Jul	Aug	Sep	Oct	Dec-19	Jan-20
Cumulative Monthly Rainfal	0	0	6	8	0	2	0	75	57	0	40	0	0	0	0	4	18	6	100
SE(+N Fert)	478	452	409	92	386	477	432	462	530	362	540	494	465	721	643	708	593	597	596
NW (Nil N Fert)	486	478	407		487	527	524	521	474	497	480	479	472	629	577	596	526	529	580

Figure 5. Pampas profile N over time, comparing N fertilised vs unfertilised, along with cumulative monthly rainfall (mm) (NOTE: The dip in the line graph represents 96 kg N applied as Urea on 20/6/18).

Where is my N in the profile (and the N fertiliser that I have previously applied)?

At the Incitec Pivot Darling Downs sites, the distribution of N in the profile has been expressed and examined as a percentage of the total of the kg N/ha in the measured profile (0-90cm).

At Dalby, Qld, the percentage of profile N in the depth segments remained largely stable except for the October 2018 sample date, following 155 mm of rainfall that month. Whilst a crop was present, the cropped plot showed an appreciable reduction in surface and subsurface nitrate N, presumably because these were the zones from which crop N uptake occurred. The difference in N distribution from July 2019 onwards in the surface 0-10 cm and sub-surface 10-30 cm layers between the area cropped to sorghum 2018-19) and the adjacent fallow area, was markedly different, until the two treatments start to align again in December 2019, some 8 months post-harvest.

At Mt Irving, the percentage of profile N at each profile depth varied. Given this site has had fertiliser N applied in July 2018; a silage corn crop grown that removed nitrogen; cultivation following the silage; and further N applied in April 2019: a natural assumption is that the distribution of N in the profile over that period would be sporadic. What is evident though is that the two N applications were not detectable as nitrate for 3-4 months from the July 2018 applied N; and 2 months after the April 2019 application. This is supported by ammonium N values being elevated following fertiliser applications prior to the product nitrifying into nitrate.

Flat N rates vs tactical 'gut feel' or soil test based N rates

Data (Walker & O'Mara, 2015) from the 35 year long term Incitec Pivot site at "Colonsay" on the Darling Downs indicates that growers could simplify their N approach by applying N rates that equal or exceed crop removal from their rotation preceding each and every crop. Whilst times of variance of 'normal' seasons may mean growers need to be more tactical, of course considering fallow length, mineralisation rates and rainfall, the measurement and management of N using soil tests to quantify the quantity and position of N in the soil profile is well warranted. Then an informed N rate can be determined to reset the system.

Conclusion

The drought conditions over the last 18 months has promoted mineralisation activity within the soils of the northern grain region. While the mineralisation process occurs in the topsoil (0-10 cm depth) and this is where the majority of nitrate N is located, there is still a natural progression of mineral N down the soil profile over the long fallow period. The periodic small rainfall events were adequate to promote some mineralisation and N movement throughout the profile and importantly into the soil depths where the highest N uptake by plant roots occurs during the key growth stages.

Of particular importance to growers in the northern grains region is that the mycorrhizae fungi (AMF) responsible for plant vigour during early seedling growth decreased to very low levels during the non-productive period (data not presented in this paper). Growers should become aware of the AMF levels and other key nutrients (P, K & Zn) within their soils before they head back into cropping and follow the best management guidelines when returning into a cropping sequence. While soils may have adequate plant available nitrogen due to mineralisation after a long fallow period, additional phosphorus, potassium and/or zinc may be required to aid potential AMF deficiency.

Quantification and measurement of yield grain nutrient content to calculate nutrient removal should be considered by growers and advisors to more closely to ascertain the magnitude of nutrient export in differing seasons, species and cropping systems. This is particularly evident where a higher frequency of legumes or higher yielding summer grain crops are grown in a crop rotation. Of heightened interest is the frequency and magnitude of removal of all nutrients, but especially the nitrogen and potassium export quantities from a rotation. The long term cropping system results show that crop type and the dry matter production play important roles in the amount of mineralisation that occurs in the subsequent fallows. As a result, mineral N could vary greatly spatially within your cropping soils.

When phasing back into a cropping rotation, it is paramount that growers test their soils, to understand the nutrient dynamics. Sampling adequately to account for the variability, position and magnitude of N (and P, K and Zn) present in profiles by segmenting their soil samples to better understand their starting point, especially for when they are re-commencing a cropping program post-drought.

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K nutrition - what's new? Measuring, using and budgeting K. Sodium interactions, placement and payoff

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Notes

Implications of continuing dry conditions on cereal disease management

Steven Simpfendorfer, NSW DPI, Tamworth

Keywords

Fusarium crown rot, common root rot, AMF, PREDICTA® B, spot form of net-blotch

GRDC code

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

Take home messages

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

Introduction

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

Potential consequences of dry conditions

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

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

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

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

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

Step 1: Know before you sow

Although paddock history can be a good guide to potential disease issues, extended dry conditions can allow damaging inoculum levels to still persist from 2-4+ seasons ago (Table 1). Hence, growers need to consider the longer-term sequences within paddocks. How cereal stubble was handled over prolonged dry conditions can also influence the survival and distribution of cereal pathogens. Paddock history is only a guide and provides no quantitative information on the actual level of risk posed by different cereal diseases.

Table 1. Decline in pathogen and beneficial arbuscular mycorrhizae fungi (AMF) levels over 20 months in a replicated cereal variety experiment at Rowena

Pathogen	13 Dec 2017	12 June 2019	% decline	Risk mid-2019
Prat. Thornei (no./g soil)	7.7	4.3	44	Medium
Common root rot (pgDNA/g)	58	38	35	Low-medium
Crown rot (phDNA/g)	579	256	56	High
AMF (KDNA copies/g)	90	55	39	Adequate

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

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

Step 2: Consider pre-sowing management options

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

Fusarium crown rot (Fusarium pseudograminearum)

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

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

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

If sowing cereal then:

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

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

If sowing cereal then:

- Choose a more tolerant wheat or barley variety for your region to maximise yield and profit (Table 2), durum is very high risk with yield loss >50% are probable in a tough finish but oats are still a decent option

- Sow at the start of a varieties recommended window for your region as this can half the extent of yield loss
- If a late break occurs consider switching to a quicker maturing wheat variety or go with barley to limit exposure to heat stress during grain filling which exacerbates yield loss
- Consider inter-row sowing (if previous cereal rows are still intact) to limit contact with inoculum
- Do not cultivate - it will spread inoculum more evenly across the paddock and into infection zones below ground
- Be conservative on nitrogen application at sowing (Figure 1) as this can exacerbate infection (e.g. consider split application) but ensure a maintenance level of zinc is applied
- Be aware that current seed treatments registered for Fusarium crown rot suppression provide limited control and get to a Syngenta learning centre in 2020
- Determine infection levels around heading (see step 4) and be prepared from sowing to cut for hay or silage if required.

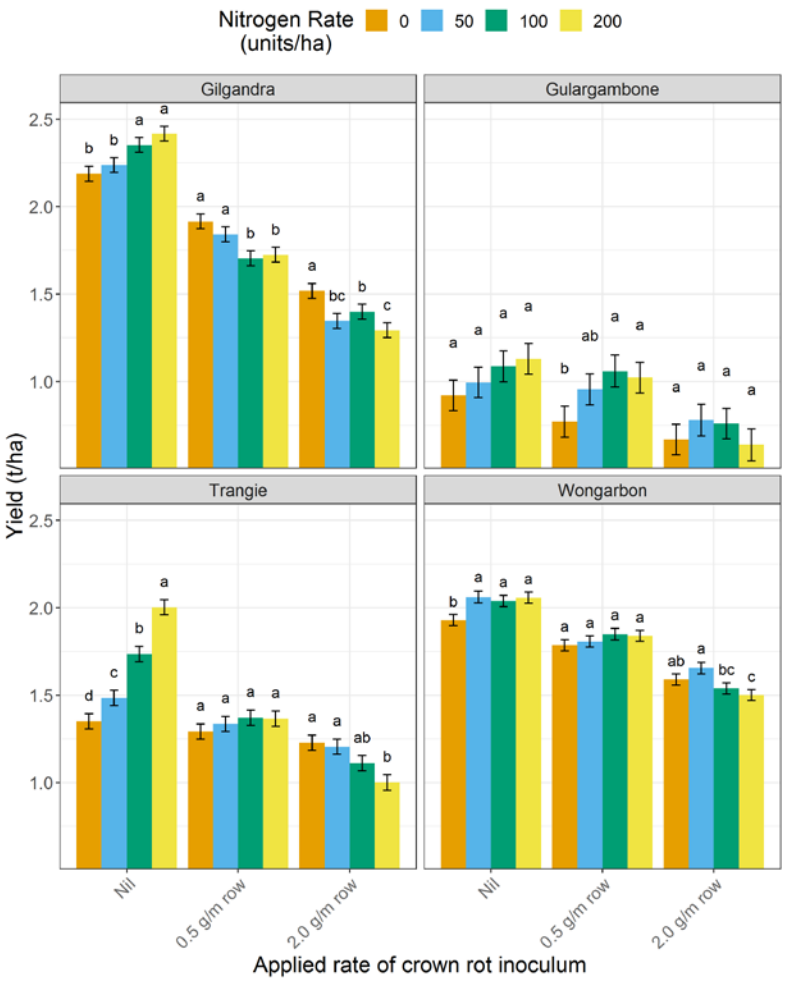

Figure 1. Interaction of nitrogen nutrition and crown rot infection on bread wheat (Suntop⑴ and EGA Gregory⑴) yield across four sites in central NSW in 2018. Note: Nil applied inoculum represents a BDL/low risk, 0.5 g/m row a medium risk and 2.0 g/m row a high risk of crown rot infection.

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

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

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

Common root rot (Bipolaris sorokiniaina)

The trend to deeper and earlier sowing of cereals into warmer soils is associated with an increased prevalence of common root rot (CRR) across Australia, especially in the northern region. Deeper sowing lengthens the sub-crown internode in cereals which increases susceptibility to CRR. Soil temperatures greater than 20-30°C, which often occur when sowing earlier, also favour *Bipolaris* infection with yield losses between 7% and 24% reported from CRR in bread wheat. However, delaying sowing to reduce CRR levels is not recommended as the negative impact on yield potential generally outweighs the impact of increased CRR. Note that CRR is also frequently found in association with crown rot, exacerbating yield loss.

Assuming the main concern is common root rot (CRR). Based on the following PREDICTA®B test results pre-sowing management options include:

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

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

If sowing a cereal then:

- Grow partially resistant wheat or barley varieties, oats and triticale may not develop severe infection but act as hosts
- Consider increasing sowing rate to compensate for potential tiller losses
- Consider inter-row sowing (if previous cereal rows are still intact) to slightly reduce infection levels
- If moisture permits, reduce sowing depth to limit the length of the sub-crown internode which is the primary point of infection
- Ensure good phosphorus nutrition which reduces severity
- Ensure good nitrogen nutrition as stunting and lack of vigour is more pronounced in paddocks that are N deficient
- Assess root health coming into Spring (see step 4).

Arbuscular mycorrhizae fungi (AMF)

AMF colonise roots of host plants and develop a hyphal network in soil which reputedly assists the plant to access phosphorus and zinc. Low levels of AMF have been associated with long fallow disorder in dependent summer (cotton, sunflower, mungbean and maize) and winter crops (linseed, chickpea and faba beans). Although wheat and barley are considered to be low and very low AMF dependent crops respectively, they are hosts and are generally recommended to grow to elevate AMF populations prior to sowing more AMF dependent crop species. PREDICTA®B has two DNA assays for AMF and it is important to remember that in contrast to all the other pathogen assays, AMF is a beneficial so nil or low DNA levels are the actual concern. It is concerning that AMF DNA was not detected in root systems of 39% of 150 cereal crops surveyed in central/northern NSW and southern Qld in 2018 (Simpfendorfer and McKay 2019). AMF levels are likely to have declined further in the northern region with continued dry conditions in 2019 (Table 1).

Based on the following PREDICTA®B test results (combining the two AMF test results) pre-sowing management options include (Chapter 10: Broadacre Soilborne Disease Manual, SARDI):

Low (<10; long fallow disorder risk high*):*

- Consider growing winter cereals which are a host but have low AMF dependency to increase population
- Avoid sowing highly dependent crops (e.g. chickpea, faba bean, sunflower, mungbean, maize)
- Do not burn stubble.

Medium (10<20):

- Avoid sowing highly dependent crops (e.g. chickpea, faba bean, sunflower, mungbean, maize) if phosphorus levels are low, including at depth
- Avoid burning stubble.

High (>20):

- Crop choice not restricted – be aware canola, lupins and long fallow will reduce AMF levels
- Grow most profitable crop.

Step 3: Ensure quality of planting seed

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

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

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

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

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

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

Common root rot does not cause distinct symptoms in the paddock. Infected cereal crops may lack vigour and severe infections can lead to stunting of plants and a reduction in tillering. These general symptoms of 'ill-thrift' in CRR infected wheat and barley crops can often go undiagnosed. This can be easily identified with the help of a shovel or spade! Simply dig up some plants around heading, wash soil away from roots and inspect the general root health paying particular attention to whether the sub-crown internode (joins seed to the crown) has partial or whole dark brown to black discolouration.

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

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

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

Dry conditions can also impact on the lifecycle of necrotrophic fungi which cause yellow spot in wheat or net-blotches in barley. We observed this around Croppa Creek in northern NSW in 2019 with spot form of net-blotch (SFNB) in barley crops. Numerous barley crops in a restricted area had decent levels of SFNB lesions on leaves during tillering. This was surprising as the season was relatively dry up to this point with only low rainfall events (<5 mm) since sowing. Rainfall events were accompanied by early morning fogs. These conditions, while not really contributing to yield potential, were enough to meet the 6 hours of high humidity (>80% RH) to initiate SFNB infections on leaves. Interestingly, due to dry conditions the primary infection propagules (pseudothecia) which have a moisture requirement had not matured on 2018 barley stubble. The primary source of infection was mature pseudothecia present on 2017 or even 2016 barley stubble. SFNB was also present in two barley crops sown into wheat stubble which was surprising. However, conidia of the net-blotch fungus *Pyrenophora teres* formed on collected wheat stubble after 4 days in humid chambers. This supports 2018 disease survey findings where the SFNB fungus was found to be saprophytically infecting wheat crops due to late rainfall in October coinciding with senescence of lower wheat leaves.

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

Conclusions

The perpetual risk as a plant pathologist is the perception that we are always the bearer of bad news or 'of the grim reaper mentality'. Elevated risk of stubble- and soil-borne diseases in 2020 is inevitable given continuing dry conditions which have prolonged survival of pathogen inoculum. However, practical steps can be taken to identify the level of risk and strategies implemented to minimise but not necessarily fully eliminate disease impacts on wheat and barley crops in 2020.

Hopefully wet conditions restrict impact of Fusarium crown rot. However, growers and their agronomists need to be prepared to inspect the root health and stem bases of cereal crops around heading to guide some potentially tough but informed decisions. NSW DPI plant pathologists are also available throughout the season to provide support.

Useful resources

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

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

Simpfendorfer S, McKay A (2019). What pathogens were detected in central and northern cereal crops in 2018? GRDC Update, Goondiwindi. https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2019/03/what-pathogens-were-detected-in-central-and-northern-cereal-crops-in-2018

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Managing chickpea diseases after the drought

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

Key words

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

GRDC code

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

Take home messages

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

How drought affects plant diseases

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

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

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

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

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

Seed quality

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

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

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

Predicta®B for assessing Ascochyta risk

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

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

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

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

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

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

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

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

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Changes in northern NSW farming system climate conditions - Bellata

Steven Crimp and Mark Howden, Australian National University

Key words

climate projections, production impacts, adaptation options

Take home messages

- Greenhouse gas (GHG) emissions continue to accumulate in the earth's atmosphere and drive warmer global temperatures. Warming of globally averaged air temperatures of just over 1°C since records began in 1850 has produced national, regional and local changes in environmental conditions. These changes have shifted debate from "Is climate change real?" to "What should we do about it?"
- Adapting agricultural practises will be required to respond to changing environmental conditions and will require all components of the agricultural value chain to work together in order to maintain resilient and profitable food systems.

Historical changes in climate?

Preliminary results suggest that 2019 is likely to be either the second or third warmest year on record, with globally annual averaged air temperatures now 1°C warmer than the long-term average calculated for the period 1961 to 1990. This warming is driven by increasing concentrations of all the major long-lived greenhouse gases in the atmosphere, with carbon dioxide (CO_2) concentrations rising from 208ppm prior to the industrial revolution, to 413.65 ppm as of 4 January 2020 (NOAA, 2020).

In Australia, warming in average temperature (average temperature) has resulted in 2019 being the warmest year on record (1.52°C above the 1961 to 1990 average of 21.8°C) (BoM, 2020). Average daytime maximum temperatures in 2019 of 30.69°C were 2.09°C above the 1961 to 1990 average. In December 2019 more than 40% of the entire country recorded maximum temperatures greater than the 97th percentile i.e. top 3% of temperatures. Examining the shift in the distributions of monthly day and night-time temperature shows that very high monthly maximum temperatures that occurred around 3% of the time in the past (1951–1980) now occur around 12% of the time (2003–2017) (BoM & CSIRO, 2018). Very warm monthly minimum, or night-time, temperatures have shown a similar change from 2% of the time in the past (1951–1980) to 12% more recently. This shift in the distributions towards hotter temperatures and more extreme high temperature conditions has occurred across all seasons, with the largest change being in spring (BoM & CSIRO, 2018).

In the Bellata region over the period 1960 to 2019 (length of the temperature record), warming has occurred in both minimum (1.6°C) and maximum temperatures (2.1°C). For the period 1960 to 1991 an annual average maximum temperature of 27°C occurred, on average, 10% of the time. More recently (1992 to 2019), this temperature now occurs on average 22% of the time. Similarly mean annual minimum temperatures have warmed, with the frequency of a minimum temperature of 12°C increasing from 21% to 25% of the time (Figure 1). As a result of the warming, the frequency of extreme minimum temperatures of -4°C have declined from 12% during 1960 to 1991 to 6% in the most recent period. The frequency of extreme maximum temperature extremes has increased, with temperatures greater than 45°C now occurring about 4% of the time (Figure 2).

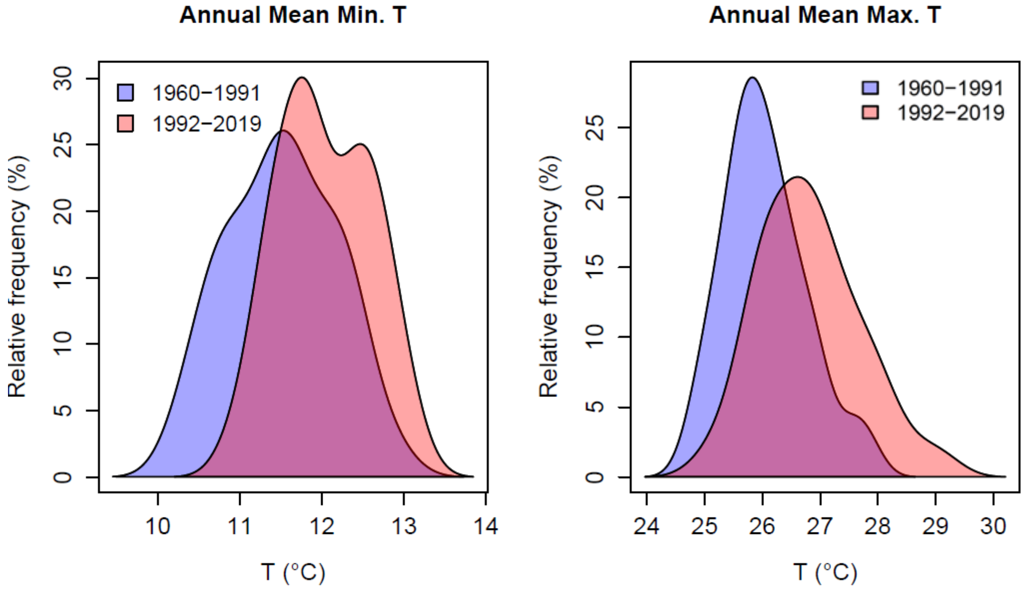

Figure 1. Probability distributions of annual mean maximum temperature (right) and annual mean minimum temperatures (left) for Bellata for two periods, namely 1960 to 1991 and 1992 to 2019.

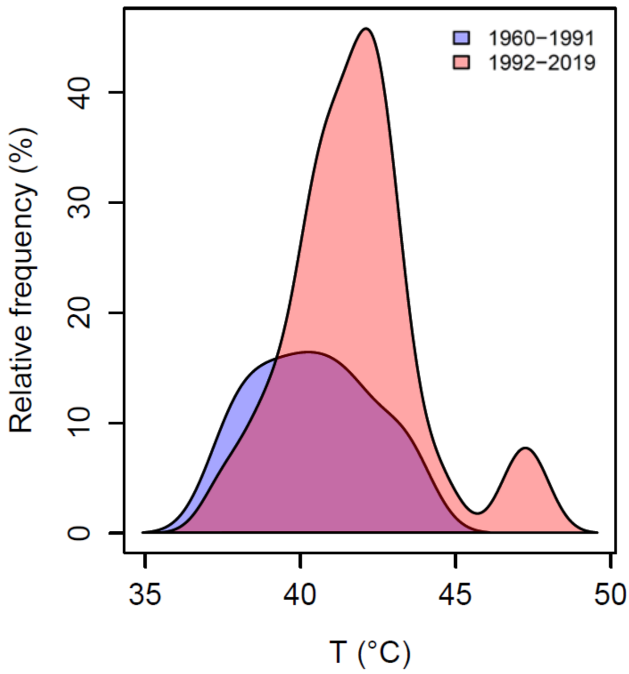

Figure 2. Probability distributions of daily maximum temperature extremes for Bellata for two periods, namely 1960 to 1991 (blue) and 1992 to 2019 (pink).

The Bellata rainfall record exhibits a declining trend, with an average 89mm less annual rainfall now than in the 1960s. A comparison of the annual rainfall between the period 1960 to 1991 and 1992 to 2019 (Figure 3) does show a slight change in the annual distribution of rainfall in the Bellata region. The analysis highlights an increase in the occurrence of low annual rainfall amounts less than 300mm in the most recent record as well as an increase in the occurrence of annual rainfall amounts greater than 950mm (Figure 3).

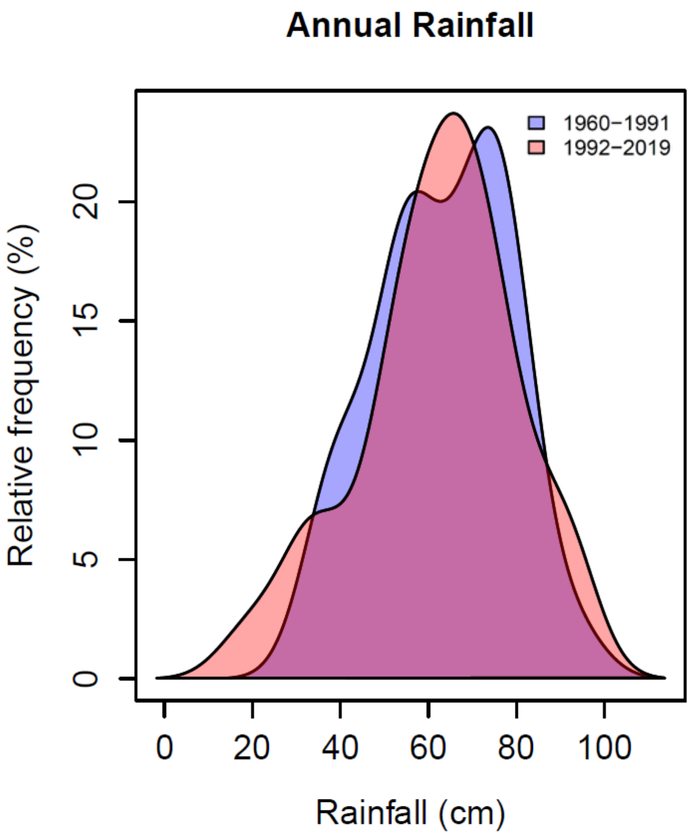

Figure 3. Probability distributions of annual rainfall amounts for Bellata for two periods, namely 1960 to 1991 (blue) and 1992 to 2019 (pink).

The current acceleration of global warming is expected to continue based on future greenhouse gas (GHG) emissions trajectories. Previous studies have examined how the rates of record-breaking have changed in the US (Anderson et al., 2011), the UK (Kendon, 2014), and Australia (Lewis & King, 2015). These studies have found increased rates of hot temperature records and decreased record setting for cold temperatures in recent decades (King et al., 2015; King, 2017). Lewis and King (2015) found that from 2000 to 2014 there were 12 times as many hot record-breaking temperatures as cold records in Australia and attributed this to anthropogenic climate change. Recent BoM analyses has shown that from 1960-2018 the ratio of hot records to cold records set across Australia was 6:1 whereas from 1910-2018 the ratio was 9:1 (Blair Trewin pers Comm. 2020). In 2019 the ratio of hot to cold records broken at the state area average level was 34:0 (Blair Trewin pers Comm. 2020). Across the world, there were about five times more record-breaking monthly temperatures than would be expected without a long-term warming trend (Coumou et al., 2013) over the early 21st century.

During the 2018/19 Australian summer more than 206 individual location extreme temperature records were broken in just 90 days (Climate Council, 2019). Climate change has been found to not only increase the likelihood of breaking high temperature records (e.g. Lewis and Karoly, 2013), but record-breaking hot summers and years over previous decades are also attributable to anthropogenic climate change (King et al., 2016). More recent research by Mann et al. (2018) has shown that the synoptic features (large scale weather systems) responsible for prolonged heatwaves are on average 50% more prevalent under a business-as-usual GHG emissions trajectory.

In addition to record breaking temperatures, changes in rainfall patterns, sea levels, rates of glacial retreat and biological responses have also been detected consistent with expected climate change projections. This mounting evidence has led to scientific consensus that:

- Emissions of greenhouse gases and aerosols due to human activities continue to alter the atmosphere in ways that affect the climate system and these changes and resultant trends will continue for the foreseeable future; and
- There is at least 95% confidence that humans are the main cause of global warming since 1950, and most likely responsible for 100% of that temperature rise (IPCC, 2018) with a less than 1 in 100 000 chance that human activities are not responsible for the observed increase in global temperatures (Kokic et al., 2014).

These changes are already likely to have negatively impacted on Australian agriculture, acting as a major drag on yield growth with similar impacts on yield growth globally for the major crops (Porter et al., 2014).

A major issue in understanding historical and future climate change is how much are the various human-induced climate forcing's (greenhouse gas emissions, stratospheric ozone depletion, Asian aerosols, and landcover change) interact with components of natural variability (Watkins, 2005, McKeon, 2006). Thus, it is important for successful climate adaptation that agricultural decision-makers keep informed of the evolving climate science and updated climate change scenarios. As scientific understanding improves and there is more confidence in emission scenarios, current and future uncertainties can be rapidly assessed in terms of decision making.

What is expected to happen in the future?

In response to the continued growth in atmospheric GHG concentrations, scientists estimate that global average temperatures could increase by up to 4.8°C by the end of the present century, dependent on global population growth, technological advancement and economic growth (IPCC, 2013). To put this in context, the difference between our historical temperatures and those of the last ice age was only about 5°C. So even though 4.8°C does not sound like much, it signals a huge change in how the climate-ocean-land systems of the earth function and hence how agriculture will operate.

In Australia, national projections suggest additional warming of up to 1.3°C of additional warming could be experienced by 2030 and up to 5.1°C of warming could be experienced by 2090, with the greatest warming being in inland Australia and the lesser warming along the southern coast and Tasmania (CSIRO, 2015). Global studies indicate that a rule of thumb is that global potential crop production drops by 6% per degree warming (Porter et al*.,* 2014).

Whilst changes in rainfall are more uncertain, projections suggest drier conditions in the southern half of Australia, particularly in the south-west and during the cool season months of May to October, with as much as 20% less by 2030 and up to 50% less rainfall by 2090 in the south-western parts of Australia by 2090, respectively (CSIRO, 2015).

At a regional scale projected change in climate for the New England and north west region (Bellata represents a town in the northwest of this study region) are summarised in Table 1. In addition to warmer temperatures. By 2030 the median value of annual potential evaporation is projected to increase by 5% under a high emissions scenario.

Table 1. Projected changes in temperature and rainfall for New England and north west region (Bellata represents a town in the northwest of this study region). Present average temperatures and rainfall are calculated for the period 1986 to 2005. The data contained in this table represents information compiled from the NSW Department of Planning and Environment.

Variable	Season	Historical mean (1986 to 2005)	2030	2070
Mean temperature change (°C change)	Annual	19.2°C	0.7 (0.4 to 1.0)	2.2 (1.8 to 2.6)
	Summer	26.0°C	0.9 (0.4 to 1.4)	2.4 (1.7 to 2.9)
	Autumn	19.6°C	0.7 (0.5 to 0.9)	2.2 (1.5 to 2.7)
	Winter	11.7°C	0.5 (0.3 to 0.7)	1.9 (1.4 to 2.4)
	Spring	19.4°C	0.8 (0.5 to 1.3)	2.3 (2.1 to 2.8)
Mean rainfall change (% change)	Annual	658mm	+1.6 (-12 to +15)	+7.7 (-10 to +25)
	Summer	245mm	-3.3 (-14 to +15)	+9.8 (-12 to +40)
	Autumn	123mm	+14.9 (-12 to +46)	+16.8 (+1.0 to +47)
	Winter	128mm	-7.6 (-29 to +16)	-0.7 (-29 to +30)
	Spring	164mm	+2.6 (-22 to +20)	-0.7 (-20 to +30)

Adapting to projected climate changes

Climate change is likely to pose a significant challenge for Australian agriculture. Of greatest concern are likely to be changes in water availability, and the change in frequency of climatic extremes (e.g. heatwaves, drought and floods).

Many of the actions required for adapting to climate change are extensions of those currently used for managing climate variability. For this reason, efforts to improve current levels of adaptation to climate variability will have positive benefits in addressing likely climate change impacts.

Examples of likely farm level adaptation options include:

- Enhancing the current implementation of zero tillage and other minimum disturbance techniques, retaining crop residues, extending fallows, changing row spacing, changing planting density, staggering planting times, traffic and erosion controls
- Alter planting decisions to be more opportunistic – more effectively taking into account environmental condition (e.g. soil moisture), climate (e.g. seasonal climate forecasting) and market conditions
- Expand routine record keeping of weather, production, degradation, pest and diseases, weed invasion
- Incorporating seasonal climate forecasts and climate change into farm enterprise plans

- Improve efficiency of water distribution systems (to reduce leakage and evaporation), irrigation practices and moisture monitoring
- Learning from farmers in currently more marginal areas
- Selection of varieties with appropriate thermal time and vernalisation requirements, heat shock resistance, drought tolerance, high protein levels, resistance to new pests and diseases and perhaps that set flowers in hot/windy conditions
- Enhance current consideration of decision support tools/training to access/interpret climate data and analyse alternative management options (e.g. APSIM, EverCrop).

There are also longer-term decisions at a family farm level - to sell up, to buy more land, where to invest. These are especially pertinent for farmers in low rainfall regions and it will increasingly be more difficult to find no-regret decisions if climate change progresses as anticipated (Hayman, 2005). These decisions, along with industry infrastructure (silos etc.) and industry support (drought policy) are hard decisions requiring full understanding of the likely future risks (Hayman, 2005).

The value of adaptation

In Australia a number of studies have examined the economic benefits of adaptation in the wheat industry at both national and regional scales under a range of likely future climate conditions. Hochman et al. (2017) highlighted that the adoption of new technology and management systems held actual yields fairly steady: without these advances, water-limited yield would have dropped by 27%. It was estimated that rainfall declines should have accounted for about three-quarters of the fall in simulated yield potential, whilst observed warming should have accounted for about a quarter of fall in yield potential.

Continued adaptation to climate change has been estimated to add an additional AU$500M per annum (Howden and Crimp, 2011) via the introduction of improved water-use efficiency options and may mitigate potential yield losses by up to 18% through broader scale adaptation (Ghahramani et al., 2015).

The results suggest a number of adaptation options exist to manage increased future downside risk, however the effectiveness of adaptation is driven by the extent of future change. Under conditions of large climate change, tactical adaptation will only have limited effectiveness and more extensive adaptation options, often defined as transformation adaptation, may be required.

Advisers have a key role to play in changing the nature of the climate change dialogue. In the space of about five years many grain growers and their advisers have moved from asking "What is climate change?" or "Is it real?" to "How do we manage for climate change?" and "What will the impact be on the grains industry?"

Advisers have a vital role to play in this dialogue, not only in assisting grain growers in reducing greenhouse gas emissions from on-farm activities, but also in developing information systems that growers can tap into in order to build farming systems that can cope with current climate variability and can adjust to ongoing climate changes.

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Measuring soil water - sensors and strategies - what works when and with what level of accuracy?

Notes

Three-dimensional measurement of soil water and subsoil constraints using electromagnetic induction

Brendan Griffiths, Andrew Smart, Sally Poole and Nick Barton, PCT Agservices

Key words

soil water measurement, subsoil constraints, EM survey, pedotransfer function

Take home messages

The challenge in our business is to develop methods of measurement of soil physical characteristics that are repeatable, reliable, and accurate to a reasonable degree of confidence. Our current work is revolving around improving the current, and often either fairly subjective, or very labour-intensive methods of assessing soil water, and also understanding and characterising the impact of subsoil constraints.

Most of the work done by PCT Agservices involves the collection and management of spatial GIS data, and applications for the use of that data via management and analytics. Our challenge has been to develop methods of measuring soil physical characteristics that are repeatable and reliable, and accurate to a reasonable degree of confidence. Work largely revolves around the spatial estimation of soil water and subsoil constraints.

A range of different methods can be used when estimating soil water. We are investigating a number of different applications for the use of spatially generated EM datasets. At present, the most repeatable and reliable method we use is derived from a pedotransfer function. These functions model a range of soil physical parameters, including soil water, based on soil textural analysis, from sand, silt, and clay.

Regression analysis is used to create a three-dimensional layer of soil water holding capacity, from geo-referenced soil test points, generated to represent the dataset from the spatially collected EM survey. This provides a modelled, unconstrained soil water holding capacity in three dimensions, and at field level.

From the same EM survey and the same geo-located soil testing points, we again apply regression analysis against other soil test data. This allows us to classify other spatial layers showing the extent of, and depth to, a range of subsoil constraints, largely related to sodicity or salinity, or both.

From this we then can gain a far better visualisation of the ability of the soil to hold water, and the things that may inhibit the ability of the roots to extract it. Once we have classified our layers of soil water holding capacity and of subsoil constraints, we can then relate those layers/datasets back against yield and/or crop biomass to gain an understanding of the extent to which those layers are influencing yield, either positively or negatively.

As mentioned, there are a several other methods/techniques that we are working on that include the use of EM as a tool to spatially estimate plant available water. This is certainly something we are close to perfecting, but at this stage more work is needed to confidently and reliably repeat the method, and we need more full profiles to work with.

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Strategies for profitable decision making in 2020

Discussion session

Notes

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