GRDC Grains Research Update Nindigully

Thursday 6th August 2015, Nindigully Hall

Registration: 8:30am for a 9am start, finish 2:45 pm

Agenda

Time	Topic	Speaker (s)
9:00 AM	Welcome	GRDC
9:10 AM	Farming systems performance: A major new farming systems project on the constraints to performance and efficiency. What's planned, where and how to engage.	Bec Raymond, DAF Qld
9:25 AM	Sorghum agronomy: managing risk and improving yield in the western zone.	Loretta Serafin, NSW DPI
10:00 AM	Chickpea and fababean agronomy.	Kerry McKenzie DAF Qld
10:30 AM	Nitrogen fixation: how much is fixed and how does it affect subsequent crop N budgeting?	Nikki Seymour, DAF Qld
10:55 AM	Morning tea	
11:25 AM	Soil tests for crown rot and nematodes: New crown-rot perspectives: Using PreDicta B vs stubble tests; sampling protocols for reliable results; applying test results to individual paddock situations.	Steve Simpfendorfer, NSW DPI
12:00 PM	Get the first, second and third punch in on feathertop Rhodes grass! Which strategies are working best?	Richard Daniel, NGA & Mark Congreve, ICAN
12:40 PM	Lunch	
1:40 PM	Integrating camera sprayers into summer fallow: strategy and farmer experience.	Phil Lockwood, Meremley Agricultural Services
2:10 PM	Sampling for P and N: when, where, how often and how intensively should you be sampling?	Mike Bell, QAAFI
2:45 PM	Close- After the Nindigully Update, AgForce Grains will be running a shed meeting for all growers, starting at 4pm at the same location.	

Contents

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Northern farming systems performance: can it be improved?

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Key words

Crop rotation, sequence, efficiency, system, economics

GRDC codes

CSA00050, DAQ00192

Take home message

GRDC is investing in research aimed at understanding how the performance of current farming systems can be improved.

Systems with different crop intensity (or frequency), crop sequences, system inputs and practices aimed at maintaining long-term soil resources are being compared experimentally.

System modifications and their interactions of these various modifications are being examined at a core experiment site on the Eastern Darling downs, and 6 regional sites across the northern region are examining locally relevant system modifications.

Experimental data and modelling are being used to assess changes and effects of the different farming systems on several attributes (e.g. water use efficiency, nutrient use efficiency, soil resource, pathogen and weed populations).

Rationale

Recent analysis suggests that there is potential to increase the efficiency of current farming systems. An analysis of surveyed crop sequences found that only 29% were achieving 80% of their potential water use efficiency. Similarly farming systems are facing emerging challenges of increasing herbicide resistance, declining soil fertility and increasing soil-borne pathogens all which require responses in farming systems in order to maintain system productivity.

The northern farming systems initiative aims to address these emerging challenges by investigating the question: Can systems performance be improved by modifying our farming systems?

The research aims to deliver information on the following issues:

- Key issues or areas where current systems are underperforming
- Benchmarks for, and gaps between, current and potential system water use efficiency (not just crop water-use-efficiency)
- What changes in farming systems enable further increases in system efficiency
- Benefits and costs of crop choices on various aspects of farming systems (water, nutrients, weeds, pests)
- Identify any possible future issues that are likely to arise in response to changes in farming systems

Experimental plans

The northern farming systems initiative will implement a co-ordinated experimental program to examine a range of modifications to farming systems and quantify their relative impact on a range of measures of system performance. These modifications have been chosen following consultations with growers, advisors and other researchers across the northern region and are targeted to address apparent current and emerging challenges to farming systems. The range of systems have been chosen to capture the range of possible cropping systems operating in the northern region.

The combined experimental program will consist of 1 core site located at Pampas on the Eastern Darling Downs and 6 regional sites located at Emerald Agricultural College (Central Queensland), Billa Billa (Western Downs/Border Rivers), Mungundi (Western NSW and Qld), Plant Breeding Institute, Narrabri (Northern NSW), Nowley Research Station, Spring Ridge (Liverpool Plains), and Trangie Research Station (Central West NSW).

The core site will compare 34 farming systems (see Table 1). These include 8 summer crop dominated systems, 8 winter crop dominated systems, 14 mixed summer-winter crop systems and 4 systems involving ley pastures. The cropping systems (not ley pasture systems) involve factorial combinations involving different crop intensity (i.e. the number of crops sown/yr), crop sequences (including the range of crops grown) and nutrient supply/balance. Each of these systems are based on differences in key decision points or rules which aim to bring about these distinct changes in the farming systems. The systems tested at the core site are common with systems being tested in the regional experimental sites.

At each regional site a 'benchmark' system, based on current decision rules used in the district, will be compared with a common set of 4 individual system modifications (i.e. higher crop intensity, higher crop diversity, high nutrient supply and high legume frequency) (see Table 2). Additional regionally relevant modifications to systems may also be included based on local demand for these treatments. Table 2 summarises the common set and different modifications to be tested at each region and the equivalent system in the core site.

Key metrics of systems performance

Over the life of the project each experimental farming system will be compared in terms of several attributes:

- Total grain production and quality
- Economics (inputs and returns)
- Efficiency of use of water and nutrients,
- Changes in soil nutrient stocks and soil health indicators
- Dynamics and populations of soil pathogens and weed populations

Together this information will be used to assess the relative performance of the farming systems against several metrics. This will help us understand the strengths, weaknesses and identify any future risks associated with particular system modifications.

Systems modelling and analysis

A combination of several modelling approaches will be used in the project to examine the performance of current farming systems across the northern region. These models will provide predictions of the likely effects of the various systems modifications over the time and extrapolate experimental information to compare system performance under a range of climatic conditions and predict the implications at other locations and/or other combinations of systems (e.g. different sequences of crops) across the northern region. In particular, the simulation modelling will enable climate and price risk factors to be analysed for each of the systems.

Table 1. List of key modification foci for changes to farming systems, their associated rationale and impacts and how the characteristics or decisions would be altered to achieve the desired outcome. System treatments in italics are those that make up the current 'benchmark' system; System treatments denoted with a ^ are included in a full factorial at the core site and denoted with a # are only singular treatments or partial factorials at the core site.

#	System modifications	Strategy	Anticipated impacts	Key characteristics & decision point change
1. CROP INTENSITY				
1A	*Moderate crop intensity ^*	*Sowing on a conservative PAW threshold*		*Higher PAW requirement to trigger a crop sowing event (e.g. 150 mm)*
1B	High crop intensity ^	Increase the frequency of crops sown in order to maximise proportion of rainfall transpired by crops	- Reduced fallow herbicide use - Increased C inputs & soil OC - Increased soil biological activity & nutrient cycling - Reduce losses of water during fallows	Lower PAW requirement to trigger a crop sowing event (e.g. 75 mm)
1C	Low crop # intensity	Reduce the risk for a particular crop by maximising soil water at sowing by proceeding with a long fallow period.	- Greatly reduced number of crops - Higher profitability per crop - Long fallow periods requiring large herbicide program and low ground cover risks	Crops only sown when very high PAW or full profile Higher value/profitability crops are sown
2. CROP DIVERSITY				
2A	*Limited crop options ^*	*Only crops with higher direct profitability are grown*	- *Soil-borne pathogens increase* - *Limited weed control & herbicide choices*	*Crop options limited to: wheat, barley, chickpeas, sorghum*
2B	Diverse crop options ^	Utilise a wider range of crops to manage the build-up and damage from soil-borne pathogens and weeds in cropping systems	- Increased soil biological activity & diversity - Alternate herbicide chemistry & hence slow HR onset	Crop choice altered to ensure 50% of crops are resistant to nematodes and no more than 2 non-resistant crops in a row. Two crops with same in-crop mode of action can't follow each other
3. NUTRIENT SUPPLY/BALANCE				
3A	*Conservative nutrient supply^*	*Manage synthetic fertiliser input costs*	- *Soil fertility declining and likely crop yield penalties in good seasons*	*Crop fertiliser budget to achieve 50th percentile yield*
3B	High nutrient supply ^	Background soil fertility is boosted and crops provided with adequate nutrients to maximise yield potential.	- Soil chemical & biological fertility is maintained or increased - Crops able to maximise their seasonal yield potential	Initial organic amendments and subsoil P application Fertiliser budget to achieve 90th percentile yield.
3C	High legume ^	Increase inputs of biological N from legumes in system to reduce fertiliser N inputs	- Reduced N fertiliser requirements - Altered weed & pathogen populations	Legumes make up 50% crops sown High biomass legumes chosen in preference
4. SOIL QUALITY RESTORATION				
4A	*No soil restoration*	*Non-grain crops are not included in crop sequences*	- *Soil quality declines and hence water capture and nutrient supply may limit system productivity*	*Grain crops only grown in crop sequences*
4B	Cover crops #	Cover crops used to restore soil cover, increase organic inputs and manage weeds and diseases	- Reduced herbicide use - Reduce N inputs for crops in rotation - Altered weed and disease populations	Cover crops after crops leaving low ground cover Brown manure (i.e. spray out) crops with yield < 50% of potential
4C	Ley pasture #	Perennial ley pastures phases to rebuild soil organic matter, nutrient levels and build disease suppressive soil biology.	- Reduced herbicide use - Reduce N inputs for crops in rotation - Altered weed and disease populations	A phase of grass and/or legume based pastures are sown in rotation with grain crops

Table 2. System modifications for experimental program at regional locations and the reference benchmark at the core site. Note the core site will also represent the Eastern Downs region farming systems.

Trt #	System	Regional sites					
		Emerald	Billa Billa	Mungindi	Spring Ridge	Narrabri	Trangie
1	'Benchmark'	*	*	*	*	*	*
2	High nutrient supply	*	*	*	*	*	*
3	High legume	*	*	*	*	*	*
4	Diverse crop options	*	*	*	*	*	*
7	High crop intensity	*	*		*	*	*
14	Low crop intensity		*	*	*	*	*
15	Ley pasture (grass only)		*				
16	Ley pasture grass + N		*				
	Integrated weed mgnt	*					
No. of systems		6	8	5	6	6	6

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Sorghum agronomy to manage risk and improve yield in the western zone

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NSW Department of Primary Industries, Tamworth

Key words

grain sorghum , row configuration, plant population, hybrid

GRDC code

DAN 00150 Sorghum in the western zone

Take home message

- Early plant sorghum currently offers a more attractive proposition to growers than late plant sorghum, mostly for logistical and rotational reasons.
- Yields during the trial seasons 2010-2013 were generally more than 1.0 t/ha higher than the long term average for this region. In these seasons, yield declined as effective row spacing increased. Solid plant > single skip = super wide > double skip where average site yields were 3.46 t/ha.
- Yields during the seasons 2013-2015 were lower yielding than the long term average, with site yields averaging 1.37 t/ha. In these seasons, there was no significant difference in yield across row configurations for three of the four sites. At the fourth site, solid plant yielded significantly less than all other configurations.
- Plant populations should be targeted in the range of 30 – 50,000 plants/ha where the expected yield is 2.0 t/ha or greater. Where expected yields are less than 2.0 t/ha, plant populations as low as 15,000 plant/ha can provide slight improvements in yield compared to 30 and 50, 000 plants/ha.
- Hybrids should be selected which have a moderate to high level of tillering as this mechanism allows plants to respond to variable environmental conditions.

Introduction

Grain sorghum remains the main summer crop in the northern grains region, with northern NSW planting on average 160,000 ha and Queensland 470,000 ha annually. The main zones for sorghum production continue to be the area east of the Newell Highway and the Liverpool Plains in NSW and the Darling Downs in Qld.

NSW DPI, GRDC and Pacific Seeds partnered in a project focused on sorghum production west of the Newell Highway in NSW in 2010. This project "Sorghum in the western zone" was targeted at investigating a range of agronomic factors in order to improve both the reliability and yield of sorghum in these areas where sorghum is not an established part of the rotation. In the area west of the Newell Highway, sorghum production is variable in area as well as production tonnes. In an attempt to boost confidence in sorghum as a reliable summer cropping option by increasing the reliability and yields of sorghum a research project was commenced in the 2010-11 season targeting the matching of suitable hybrid types to optimum plant populations and row configurations. This research has led to a series of recommendations for the low- medium rainfall zone.

The data presented in this paper is a compilation of the results of five years of research in the western zone.

A series of twelve dryland trials was conducted over five years; from 2010 – 2015 at sites west of the Newell Highway. Trials were located at; Mungindi, Morialta Junction, Rowena, Tulloona, Gurley, Garah, Bellata, Ashley and Bullarah. The trials focused on establishing a data set around three primary factors; row configuration, plant population and hybrid selection although additional data was gathered from each site on issues such as crown rot, soil water and nitrogen use.

In order to reduce the risk of total crop failure as well as increase yield potential for sorghum producers in this zone, four primary areas are discussed in this paper; sowing time, plant population, row configuration and hybrid type selection.

Sowing time

Seven of these trials were planted in the early planting window, between September and October and five of these trials were planted in the late planting window of January. The five late plant trials were in the 2012/13 and 2014/15 growing season.

Average yields from the seven early plant trials ranged from 4.53 t/ha down to 0.74 t/ha. In comparison yields from the five late planted trials, ranged from 4.30 t/ha down to 1.59 t/ha.

While it is not possible to draw firm conclusions on which planting time is preferred from this data set (long term modelling would assist), it is worth suggesting from this data that early plant sorghum (Sept/ October) has yielded more and also has been a better fit within the farming system than late plant sorghum.

Early plant sorghum, typically sown in September/October is intended to escape the summer heat at flowering; as well as splitting the labour/ equipment requirements more evenly across the year so winter crop planting and summer crop harvest rarely coincide. Early planted sorghum is also typically harvested while conditions are still warm meaning a quick dry down time without grain drying and harvest before the pressures of winter planting. The early harvest timing also allows the option of a double crop back into chickpeas or a winter cereal should sufficient rainfall occur to fill the profile sufficiently, thus expediting the move back into a winter cropping sequence. On the downside, cool soil temperatures with the early planting time can slow early growth and sometimes affect establishment.

Late planted sorghum typically avoids the heat at flowering, but is planted into high soil temperatures which rapidly dry out the seedbed. In addition most growers in this western zone are unwilling to let an early planting opportunity pass them by in case there is not another opportunity to plant. Late plant sorghum also comes with the risk of cool temperatures during flowering and sorghum ergot. Late planting also means late harvest where dry down may be slow and difficult due to high grain moisture resulting in the need to dry sorghum grain as well as the crossover with winter planting causing additional demands on labour and machinery. Late planted sorghum also usually means the need to either short fallow to another summer crop or long fallow to the next winter crop, reducing the cropping frequency and subsequent cash flow.

Currently the case for or against early or late sowing time is largely based on the impacts on the farming system as there is insufficient data to build a more robust case on the impact on crop yield.

Crop modelling has provided simulated data across multiple years and seasons which suggest late planted sorghum to be the more reliable.

Hybrid selection

In this research project three hybrid types were selected with diverse plant characteristics to compare hybrids with varying levels of tillering and staygreen. The three hybrids selected and their characteristics were:

1. Low tillering, High staygreen – 2436 and LT10 (both experimental lines) and MR Apollo
2. Moderate tillering, moderate staygreen – MR 43

3. High tillering, low staygreen – MR Bazley

In these trials, across all sites and seasons, the hybrids with moderate to high levels of tillering have produced higher yields with the hybrids MR Bazley and MR 43 have been higher yielding than 2436, LT10 or MR Apollo by on average 0.35 t/ha (Table 1). The full potential of stay green as a plant characteristic has not been seen in this research either as the majority of seasons had higher than average yields or post-anthesis stress did not occur.

The general conclusion has been that hybrids with a low level of tillering have not been able to respond to the variable seasonal conditions by producing additional tillers (which equates to more heads) to capture additional yield potential unlike the hybrids with moderate to high levels of tillering, in this case MR 43 and MR Bazley. There has been very little difference in the grain yields of the moderate and high tillering hybrids.

Row configuration

The most common row configuration in the western zone was double skip until recent years where there has been more interest in the 1.5 m super wide row configuration.

Four row configurations were used at the trial sites; a 1.0 m solid plant, single skip, double skip and a super wide (1.5 m solid) with the exception of Byra in the 2012/13 season which was on raised beds so a 2.0 m solid plant was substituted for a super wide configuration.

Across these twelve trials, where site yields were greater than 1.0 t/ha, the yields declined as effective row spacing increased, hence solid > single skip = super wide > double skip. At only one site; Ashley 2014/15; where yields were below 1.0 t/ha for all configurations, was the solid plant significantly lower yielding than all other configurations.

The solid plant configuration produced the highest yields, on average 3.50 t/ha, compared to 2.98 and 2.91 t/ha for single skip and super wide respectively and 2.40 t/ha for double skip. The one trial site with a 2.0 m solid plant treatment averaged 3.13 t/ha. This equates to solid plant yielding 15-17 % more than the single skip or super wide and 31% more than the double skip.

The average yield of these sites was 2.94 t/ha which is around 0.5 t/ha higher than the long term average for grain sorghum in the North West NSW at 2.49 t/ha (NSW DPI Grains Report 1992-2012). This reinforces that the majority of the sites have been conducted in seasons that were more favourable than is the norm for these environments.

The data supports two conclusions, firstly that in above average seasons the solid plant configuration will always yield the highest, however it also comes with a greater risk of total crop failure in the low yielding seasons. Secondly, that double skip configurations sacrifice significant yield potential but are inherently a safer option as they store more water in the “skip” area for use during grain fill.

Overall, to date it seems that single skip or the super wide treatment are the preferred options for growers in this zone as they offer a more reliableoption in the dry seasons, and higher yields than the double skip, reducing the overall risk of growing sorghum in these environments.

Plant population

Over the research project four plant populations were targeted; 15, 30, 50 and 70,000 plants/ha; but only three populations were trialled at each trial site. The 30 and 50,000 plants/ha treatments were included in all trials.

In the 2010/11 and 2011/12 seasons there was no statistical difference between the yields from the 50 and 70,000 plants/ha treatments; which both produced the highest yields; as such the 70,000 population was dropped from the treatment set as it incurred additional seed costs without providing additional return and lower populations were preferred by growers.

The 15,000 plants/ha treatment was added as "how low can we go?" ; a common question from growers and advisors. From this research the 15,000 treatment has always yielded lower than the 30 and 50,000 plants/ha except where the average site yield was less than 1.6 t/ha. At the two sites where average yields were less than 1.6 t/ha, the 15,000 plants/ha treatment yielded significantly more than the 30 and 50,000 plants/ha treatments.

It should be noted though that establishing a uniform plant stand with a target plant population of 15,000 plants/ha commercially is a lot more difficult with airseeders, the more common planter in this zone for sowing sorghum.

Average yields of the twelve trial sites showed an increase of 1.55 t/ha as plant population increased from 15 to 70,000 plants/ha. However there was little distinction between the 30 and 50,000 plants/ha treatments.

Conclusions

In order to minimise risk and optimise yield in grain sorghum in the low- medium rainfall zone there is a greater emphasis on matching agronomic management to the environment than there is on hybrid selection.

Certainly hybrids have a role to play based on their suitability for environmental conditions and the relevant plasticity of their characteristics such as tillering, however in the trials conducted across both projects to date, the genetic potential of the hybrid has rarely been the limiting factor.

Currently the recommendations for sorghum in this zone, is to plant as early as possible, selecting either a single skip or super wide configuration and establish an even population of between 30 – 50,000 plants/ha using a hybrid with at least a moderate level of tillering. An additional season of trial data is planned for this coming season, 2015/16 and will hopefully provide the final conclusions to the main management decisions for sorghum growers in this region.

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Table 1. Impact of hybrid type on yield (t/ha) in 2010-2015

Hybrid Type	**Site/ hybrid**	**Gurley 1011**	**Mungindi 1011**	**Rowena 1011**	**Morialta 1112**	**Rowen a 1112**	**Bullarah 1213**	**Byra 1213**	**Gurley 1213**	**Tulloona 1314**	**Ashley 1415**	**Gurley 1415**	**Bellata 1415**
Low tillering, high staygreen	**2436**	-	-	-	3.32	4.13c	3.71b	3.89	3.09b	0.80c		-	-
	LT10	3.31	3.58c	2.59b	-	-	-	-		-		-	-
	MR Apollo									-	0.76	2.11	1.41b
Mod. tillering, mod. staygreen	**MR 43**	3.81	4.63a	3.05a	3.24	4.62b	4.63a	3.91	3.80a	1.00b	0.71	2.22	1.64a
High tillering, low staygreen	**MR Bazley**	3.81	4.47ab	2.46b	3.34	4.81a	4.61a	3.77	3.67a	1.32a	0.76	2.10	1.73a
	CV%	*n.s.d*	*10.6*	*25.8*	*18.3*	*7.2*	*12*	*13.6*	*19.2*	*16.1*	*15.8*	*19.8*	*14.7*
	L.s.d.	*n.s.d*	*0.20*	*0.33*	*n.s.d*	*0.16*	*0.25*	*n.s.d.*	*0.32*	*0.08*	*n.s.d*	*n.s.d*	*0.12*

Table 2. Effect of row configuration on yield (t/ha) in 2010-2015

Site/ Row Configuration	**Gurley 1011**	**Mungin di 1011**	**Rowena 1011**	**Morialt a 1112**	**Rowena 1112**	**Bullarah 1213**	**Byra 1213**	**Gurley 1213**	**Tulloon a 1314**	**Ashley 1415**	**Gurley 1415**	**Bellata 1415**
Solid (1.0m)	4.58a	5.38a	3.22a	3.47	5.24a	5.29a	5.29a	4.46a	1.04	0.58b	1.87	1.55
Single Skip	3.52b	4.28b	2.63b	3.42	4.59b	4.22c	4.26b	3.33bc	1.07	0.74a	2.24	1.52
Super wide (1.5m)		3.84bc	2.88ab	3.83	4.73b	4.42b	3.13c	3.64ab	1.02	0.78a	2.27	1.75
Double Skip	2.83c	3.41c	2.08c	2.48	3.52c	3.32d	2.75c	2.64c	1.04	0.87a	2.19	1.60
CV %	*11.6*	*10.2*	*25.8*	*18.3*	*7.2*	*12.0*	*13.6*	*19.2*	*16.1*	*15.8*	*19.8*	*14.7*
L.s.d	*0.52*	*0.78*	*0.38*	*n.s.d*	*0.37*	*0.17*	*0.55*	*0.96*	*n.s.d*	*0.16*	*n.s.d*	*n.s.d*

Table 3. Effect of plant population on yield (t/ha) in 2010-2015

Site/ Plant Population	**Gurley 1011**	**Mungindi 1011**	**Rowena 1011**	**Morialta 1112**	**Rowena 1112**	**Bullarah 1213**	**Byra 1213**	**Gurley 1213**	**Tulloona 1314**	**Ashley 1415**	**Gurley 1415**	**Bellata 1415**
15,000	-	-	-	-	-	4.15	3.66b	3.25b	1.05	0.87a	1.97b	1.83a
30,000	3.48	3.99	2.82a	2.56b	4.40	4.39	3.90a	3.60a	1.02	0.71b	2.13ab	1.62b
50,000	3.70	4.28	2.75ab	3.48a	4.60	4.40	4.01a	3.70a	1.05	0.65c	2.33a	1.33c
70,000	3.75	4.41	2.53b	3.87a	4.58		-	-	-	-		-
CV%	*12.0*	*10.6*	*25.8*	*18.3*	*7.2*	*12*	*13.6*	*19.2*	*16.1*	*15.8*	*19.8*	*14.7*
L.s.d.	*n.s.d*	*n.s.d*	*0.22*	*0.61*	*n.s.d*	*n.s.d*	*0.21*	*0.29*	*n.s.d*	*0.05*	*0.22*	*0.15*

Chickpea and faba bean agronomy – ideal row spacing and populations.

Kerry McKenzie[1], Bec Raymond[3], Howard Cox[1], RCN Rachaputi[2], Nikki Seymour[4]

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Key words

Chickpea, faba bean agronomy, row spacing, plant population, nitrogen fixation

GRDC code

UQ00067

Take home message

- Changes in agronomy can affect yield of pulses.
- In general increasing row spacing may decrease yield of chickpea and faba bean varieties, even in a dry season.
- Small plot chickpea yields of 4.7t/ha achieved.
- Faba bean yields to 5.5t/ha on narrow rows.
- Amount of nitrogen fixed reduces with wider row spacing.

Background and aims

Despite the potential environmental and economic benefits, the adoption of winter and summer pulse crops in the Queensland Grains Region is around 8% and 4% of total cropping area respectively, much less than what is required to keep grain cropping systems profitable in the long term. To increase the share of pulses in the total cropping area, strategies are required to enable growers to more consistently realise the potential productivity and profitability of pulse cultivars in their farming systems.

Winter pulses (chickpea and fababean) currently comprise approximately 8% of total cropped area in the Queensland Grains Region although the adoption varies from 5 to 12% depending on the growing region. Chickpea (*Cicer arietinum*) is the most adapted winter pulse crop in the Queensland with the area expanding to historically high levels in 2010. Seasonal yields of chickpea ranged from 0.5t/ha to 2t/ha depending on the timing and severity of biotic and abiotic stresses during the growing season. Although yields as high as 2.5t/ha have been achieved in varietal evaluation trials, the average yield during the 2008 – 2011 was approximately 1.2t/ha in the focus regions included in this project (Source: ABS statistics), suggesting a significant potential to increase productivity. A modest 10% increase in yield would result in a $20 to $25 increase in gross margin (based on a $200/ha gross margin). Over a winter pulse area of 125,000 ha, the increase in crop production would be valued at $2.5 to $3 million per annum.

Although the area sown to winter pulses in Queensland has increased over the last three years, there have been many challenges for growers with erratic seasonal conditions and a range of disease pressures on yield and quality. Growers' attitude to pulse crops is also influenced by forecast prices relative to other cropping options including cotton and experiences from the previous season. The area of winter pulses in the region needs to be stabilised and the reliability of achieving seasonal yield potential improved.

The Pulse Agronomy project has consulted widely within the pulse industry to determine the priorities to be investigated throughout the term of the project.

Chickpea trials 2013/14

The trials have been based on 3 varieties, PBA HatTrick ⊕, PBA Boundary ⊕ and CICA0912 an advanced breeding line, three row spacings (0.25m, 0.50m and 1.00m) and 3 or 4 plant densities (10, 20, 30 and 40plm^2).

Over 2 years 6 trials have been planted on the Darling Downs and the Border rivers region. While these sites are not around Nindigully/ St George areas, the range of seasons and soil types suggests that results will be transferrable to such areas.

Row spacing results and discussion

In the first year of trials in 2013 at a high yielding site at Dalby the top yield was 4.7t/ha. This was delivered by the pre release line CICA0912 grown on a 25cm row spacing, this row spacing also provided the highest yield for the 2 commercial lines.

At the Billa Billa site the narrow row spacing of 25cm also produced the highest yield.

Table 1. Chickpea grain yields from 2 sites at different row spacings, 2013

Row Spacing (m)	Dalby Grain Yield (t/ha)	Billa Billa Grain Yield (t/ha)
0.25	4.5 a	1.9 a
0.50	4.2 b	1.8 b
1.00	3.6 c	1.6 c
	P < 0.001, LSD = 0.1375	P<0.005, LSD=0.3984

Both of these sites had limited in crop rainfall. The Dalby site had just under 130mm for the season however the majority of this was up till late July with a dry finish combined with high daytime temperatures meaning the crop grew mostly on stored moisture. The Billa Billa site received just under 60mm in crop and again had a hot dry finish. WUE at both sites were above what is considered the average for chickpeas, with figures of 13.2kg/mm/ha at Billa Billa and up to 17kg/mm/ha at Dalby.

In 2014 4 trial sites were established, again on the Downs and at Billa Billa with another site near Garah.

Billa Billa

The trial site was 40km NE of Goondiwindi on a well-structured, uniform deep to very deep, fine, self-mulching, cracking clay, grey vertosol and was planted into standing wheat stubble. The starting soil water content was 132mm in 120cm profile and the crop received 82mm of in-crop rain.

Results

There was no significant difference between cultivars at Billa Billa nor between 25 and 50cm rows (except for PBA Boundary), however there is difference when it comes to the 1.0m rows). From this trend it can be assumed that 1.0m row spacing is not optimal at this site.

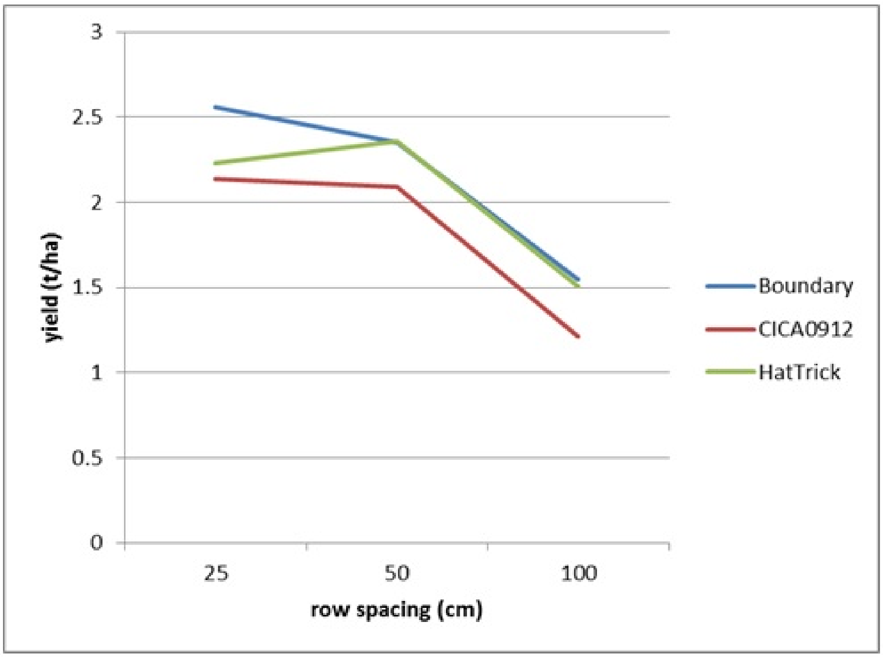

Figure 1. The effect of row spacing and cultivar on yield at Billa Billa, winter 2014 (LSD (5%) = 0.323)

Water use efficiency

Water use efficiency is a valuable measure of the potential suitability of a crop especially in the northern grains region farming systems where rainfall can be limited and temperatures high. Values for chickpeas are usually in the range of 7 to 8 kg/ha/mm water used, at Billa Billa, above average water use efficiencies were achieved.

Narrow row-spacing produced the highest WUE and PBA Boundary ⦶ produced a higher WUE but statistically it was the same as was achieved by PBA HatTrick ⦶. Effects of row spacing was significant with 25cm resulting in higher WUE (13.l kg/mm) compared to 8.4 kg/mm in 100cm rows. However, cultivar differences for WUE was not significant. A statistically higher result in all three cultivars in the 25cm spacing over 100cm.

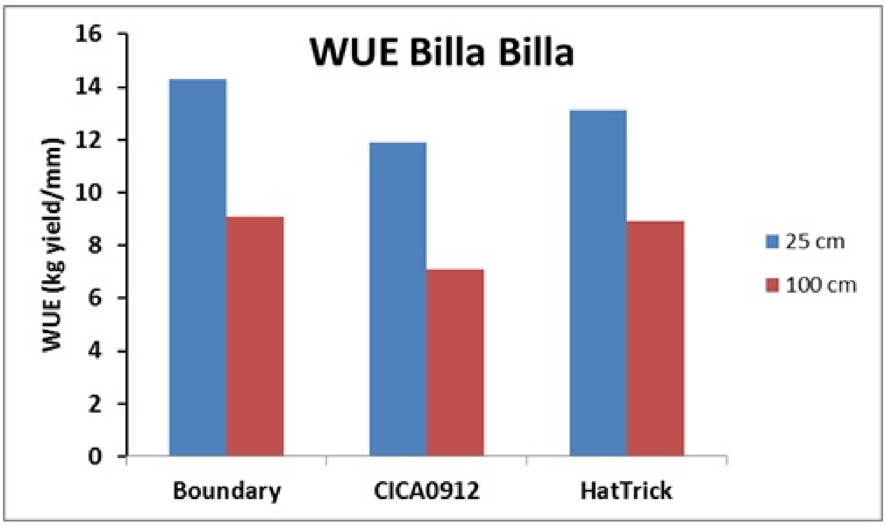

Figure 2. The effect of row spacing and cultivar on water use efficiency at Billa Billa, winter 2014 (LSD 5% = 6.72)

Garah

The trial design was similar to the Billa Billa site, the chickpeas were planted into standing wheat stubble into a grey vertosol soil, with low planting moisture but opportunistic rain post planting.

Results

Overall, low to average yields were obtained at the Garah site but significant affects from the agronomic treatments were achieved. The lower yields were due to a very low starting moisture and low rainfall throughout the season.

The highest yielding treatments being all varieties on 25cm, were 66% greater than the lowest yielding treatment (varieties at 100cm). There was deemed to be no significant difference overall between the cultivars. With the row spacing trial the trend is indicating that narrower row spacings are achieving higher yields in all three cultivars.

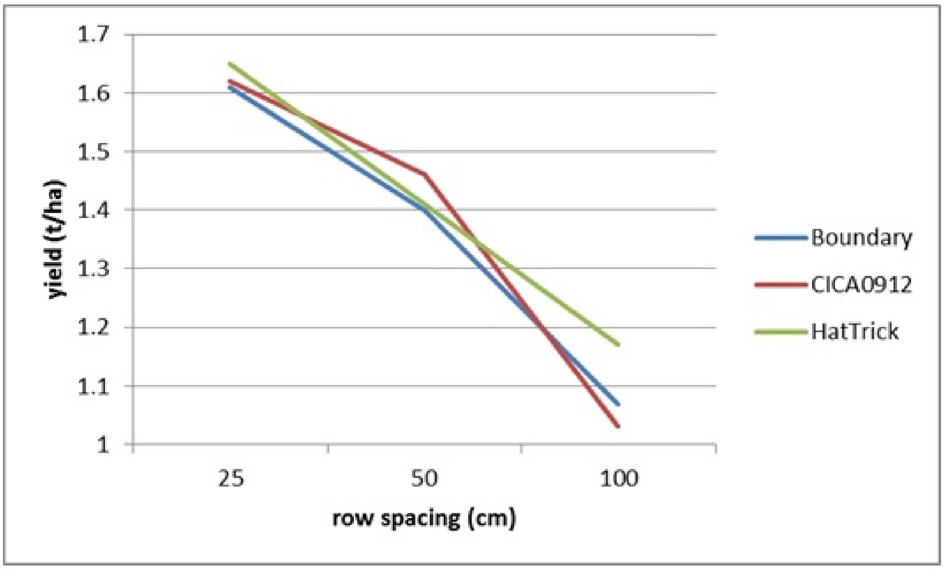

Figure 3. The effect of row spacing and cultivar on yield at Garah, winter 2014 (LSD (5%) = 0.288)

The results for the Downs are in 2014 are not presented here, however the same trend is apparent with most varieties producing their best yields on the 25cm row spacing and lowest on 1m row spacings.

Plant population results and discussion

Across 2 years and 6 sites there has been no significant differences in grain yields from altering the plant population. In 2013 the treatments were 20, 30 and 40, and in 2014 an additional treatment of 10 plants/m^2 was added. The results are almost flat across 20, 30 and 40 plants/m^2, in 2014 there was a trend for lower yield at 10 plants/m^2, however not statistically different.

The recommendation would be to continue to target the recommended planting rate to establish between 20 and 30 plants/m^2. If there is poor establishment for whatever reason, while there will be a yield penalty at lower populations a replant may not be necessary until the population is below 10 plants/m^2 (assuming a uniform distribution).

Faba bean trials 2014

2014 was the first year that any faba beans trials were included in the project and 3 sites were established. Two sites tested similar row spacings to chickpeas (25, 50, 100cm) at Dalby and Garah, with a time of sowing trial at Dalby.

Garah

The trial design consisted of 3 varieties Cairo, PBA Warda ⒫ and a pre-release line X220-D grown at 3 row spacings (0.25m, 0.5m, and 1.00m) with a targeted density of 25 plants/m^2. The trial was planted on grey vertosol which had been on a long fallow prior to planting. The crop received 96mm of in crop rain.

Results

Overall, above average yields were obtained at the Garah site and significant effects of the agronomic treatments. The highest yielding treatment was 60% greater than the lowest yielding treatment. There was deemed to be no significant difference overall between the cultivars PBA Warda ⒫ and Cairo ⒫ however the breeding line X220-D performed significantly better than the other two varieties (Table 2).

Table 2. Effect of cultivar on yield, Garah (LSD = 0.482, P=0.05)

Cultivar	Grain yield (t/ha)
PBA Warda ⒫	4.41
Cairo ⒫	4.09
X220-D	4.94

The narrow row spacing of 0.25m has significantly out yielded other spacings at 5.51t/ha (Table). X220-D was significantly higher yielding than the other two cultivars at 0.25m and at 0.5m while there was no significant difference between the 1.0m treatment.

Table 3. Effect of row spacing on yield, Garah (LSD = 0.513, P=0.05)

Row Spacing (cm)	Mean Yield (t/ha)
25	5.51
50	4.95
100	3.25

Similar to the Warra site, the same trend can be found when comparing the effect of row spacing and cultivar on yield, narrower rows are gaining the highest yields (Figure 4). The pre-release variety, X220-D yielded 20% greater in the 0.25m and 0.5m treatments than both PBA Warda ⒫ and Cairo ⒫.

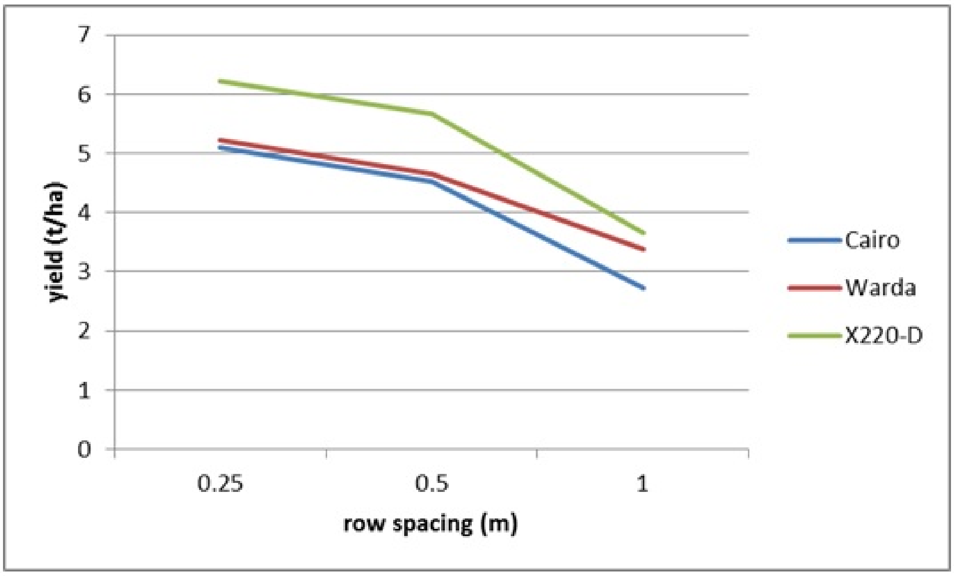

Figure 4. Effect of row spacing and cultivar on yield of faba bean, Garah, winter 2014 (LSD 5% = 0.84)

Warra

The trial design consisted of 2 varieties PBA Warda ⓓ and X220D (a pre-release line) grown in 3 row spacing (0.25m, 0.5m, and 1.00m) at a density of 30 plants/m2. The soil type is a grey cracking clay vertosol and the trial was planted on an available water content of 140mm in 0- 120cm profile. The crop received 113mm rainfall during the season.

Results

Overall, there was no significant difference between the two cultivars (the breeding line X220-D achieved marginally better yields than PBA Warda ⓓ. However, significant effects of the agronomic treatments were observed with both varieties responding positively to decreasing row spacing.

Table 4. Effect of cultivar on yield, Warra, winter 2014 (LSD = 0.4915, P=0.05)

Cultivar	Grain yield (t/ha)
PBA Warda ⓓ	3.081
X220-D	3.252

When comparing the row spacing there is a trend indicating that narrower rows are producing higher yields. There is significant difference in yield between the 0.25m and 0.5m spacing as well as the 1.0m treatment (Figure 5). However, the yield response of the pre-release line X220-D to decreasing row spacing was consistent whereas the yield increment between 0.50m and 0.25m was marginal for PBA Warda ⓓ.

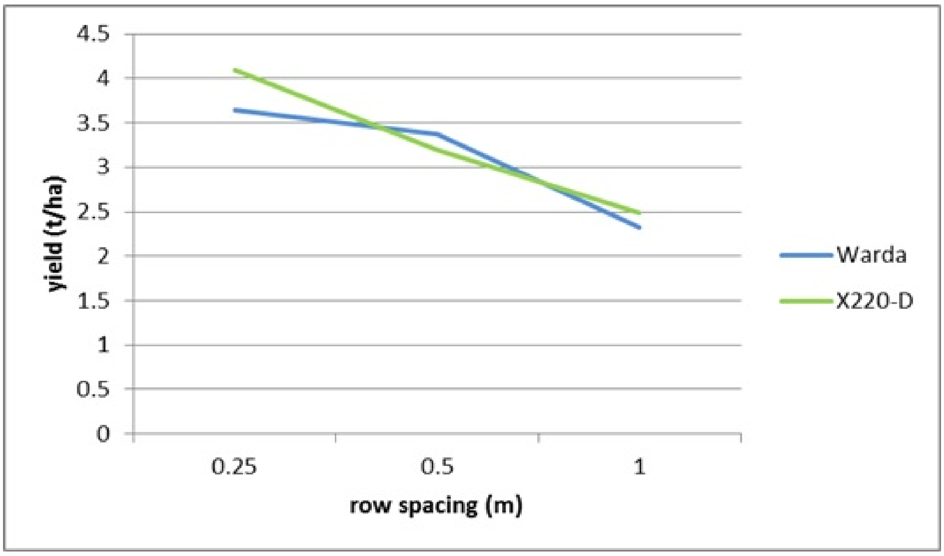

Figure 5. Effect of row spacing on yield of two faba bean varieties, Warra, winter 2014 (LSD 5% = 0.52)

Effect of time of sowing on yield of faba bean

This preliminary trial was planted and managed by Glenn Milne near Dalby. The variety PBA Warda ⓓ was planted into standing corn stubble on a well-structured, uniform deep to very deep, fine, self-mulching, cracking clay, with a targeted plant population of 25plants/m^2 on 32cm row spacing and there were three times of sowing:

1. 23 April 2014
2. 19 May 2014
3. 9 June 2014

There was a linear reduction in yields as the planting time delayed beyond 23 April (Fig 3). However, there was no significant difference in yield between the first and second dates nor the second and third dates but there is between the first and third dates. The first planting date (23 April) had the highest yield at 1.82t/ha, followed by the second date at 1.43t/ha and then the latest at only 0.99t/ha. This trend indicates that there is a need to investigate earlier dates of sowing with more varieties for the Southern Downs region for achieving higher yields.

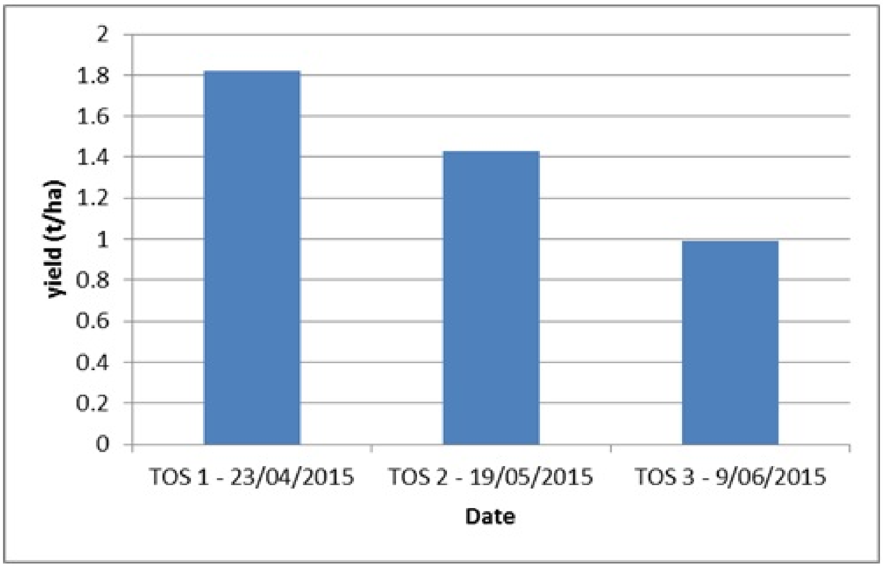

Figure 6. Effect of time of planting on yield of faba bean, Dalby, 2014 winter (LSD = 0.593, P=0.05)

Nitrogen fixation

In the 2013 season the effect of row spacing on the amount of nitrogen fixed was tested in the chickpea trials. There were no differences in N fixation amongst varieties but row spacing significantly decreased %Ndfa (nitrogen derived from the atmosphere) and total amount of N fixed, particularly at the Dalby site (Table 5).

The net N balance for each of the sites also showed a significant impact of row spacing and of the site. Up to 59 kg N/ha remained at the Dalby site when chickpeas were grown on 0.25m rows but only 23 kg N/ha from the 1.0 m row spacing. At Goondiwindi, the net N balance ranged from 6 down to -6.4 kg N/ha as row spacing increased from 0.25m to 1.0m. Our values were similar to those measured by Schwenke *et al.* (1998) who found lower N fixation in chickpeas in the drier year (1994) of their survey of commercial crops in northern NSW. As a crops' demand for N increased so did the N fixation by that crop as seen at our Dalby trial grown under better seasonal conditions. However, the row spacing effect cannot simply be explained by higher plant N demand as all crops were at the same plant population density of 30 plants/m^2. On-going trial work in 2014 will examine links of N fixation with changes in other agronomic factors (eg. soil temperatures and water use efficiencies) due to different row spacing.

Table 5. Reduction in N fixation and total amount of N fixed in chickpea (meaned across 3 genotypes) as row spacing in the field increases

	% Ndfa		**Total Crop N Fixed (kg/ha)**	
Row Spacing (m)	Dalby	Billa Billa	Dalby	Billa Billa
0.25	61.0 a	39.2	187.3 a	62.8 a
0.5	55.8 a	36.1	161.9 a	48.0 ab
1.0	47.6 b	36.3	122.5 b	42.0 b
LSD (P=0.05)	7.0	n.s	31.5	16.3

Summary and conclusion

- Narrow row spacing (25cm) consistently yield higher than wider row spacings (75cm and above) for both chickpeas and faba beans.
- This effect has been seen across 2 years and differing seasons and environments.
- Row spacing has a larger effect on yield than plant population.
- Earlier planting of faba beans is best to maximise yields, however further trials are required to determine what is too early.

References

Schwenke GD, Peoples MB, Turner GL and Herridge DF (1998) Does nitrogen fixation of commercial, dryland chickpea and faba bean crops in north-west New South Wales maintain or enhance soil nitrogen? Australian Journal of Experimental Agriculture **38**, 61-70.

Acknowledgements

Many thanks to supporters of the trials from Stephen Krosch, Katrina Conway, James McLean, trial co-operators Glenn Milne, Wade Bidstrup, Ben Moloney and the Woods Family.

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

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Fixing more nitrogen in pulse crops

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Key words

Pulses, nitrogen fixation, nitrogen balance

GRDC code

DAQ00180, DAQ0018, UQ00067

Take home message

- The amount of N fixed by a pulse crop is largely influenced by how well that crop grows. More crop biomass =more N fixed by that crop provided it is well nodulated.
- The amount of N fixed by a legume does not equal the amount available for the next crop. N is removed in the harvested grain and that N remaining in the crop residue then needs to be mineralised by microbial activity before it is available to the next crop.
- Row spacing in chickpeas of 0.25 lead to greater biomass, yield and increased N fixation than at 1.0m
- Sowing at the optimum time for maximum crop biomass leads to greater amounts of N fixed.

Nitrogen fixation

In Australia, legume-rhizobia associations are estimated to fix approximately 2.7 million tonnes of nitrogen (N) each year, worth about $4 billion. On average, this equates to about 110 kg of N per hectare per year, however the range of values can be from zero to 400 kg N/ha.

The actual amount fixed depends on the species of legume grown, the site and the seasonal conditions as well as agronomic management of the crop or pasture. The legume crop uses this N for its own growth and may fix significantly more than needed, leaving a positive N balance in the soil for proceeding crops. Estimates of the amounts of N fixed annually by some crop legumes in Australia are given below in Table 1. These are averages based on many studies over many seasons so do not represent every paddock. They do indicate the relative differences between legume species in their capacity to fix N.

The amount of N fixed by a legume increases as legume biomass increases but is reduced by high levels of soil nitrate. In general, legume reliance on N fixation is high when soil nitrate levels are below 50 kg N/ha in the top metre of soil. Above 200 kg N/ha, nitrogen fixation is generally close to zero. The fixed N is used for the growth of the legume itself (saving fertiliser application of the legume crop) as well as potentially leaving residual N for the following cereal or oilseed crop and providing a break from cereal stubble and soil-borne diseases.

Maximising N fixation in grain legumes is dependent on firstly inoculating the legume seed with the appropriate rhizobia strain (Group), then optimising basic agronomy so as to maximise legume productivity. Nitrogen fixation is directly related to biomass production for a particular species if that crop is well nodulated. Other factors though such as soil nitrate levels will influence the amount of N fixed by that crop.

Table 1. Estimates of average amounts of N fixed annually by different crop legumes in Australia.

Legume	%N fixed	Shoot dry matter (t/ha)	Total crop N (kg/ha)	Total N fixed (kg/ha)
Soybean	48	10.8	373	180
Faba bean	65	4.3	172	110
Pea	66	4.8	162	105
Peanut	36	6.8	268	95
Chickpea	41	5.0	170	70
Mungbean	31	3.5	109	34
Navy bean	20	4.2	148	30

Agronomy influences N fixation

The impacts of varying agronomic practices on N fixation are being assessed on trials grown in different environments under the GRDC Pulse Agronomy Initiative in the northern region. Two aspects, row spacing and time of sowing, will be discussed below.

Row spacing

Two trials conducted recently on the Downs (near Goondiwindi and Dalby) were assessed for the amount of N fixation at different row spacings (all at the same plant population of 30 plants/m^2.) Yields were considerably lower at the Goondiwindi site (ranged from 1.5 to 2.1 t/ha) compared to the Dalby site (from 3.2 to 4.7 t/ha) due largely to better seasonal conditions at Dalby, and there was a significant site x genotype x row spacing interaction. Generally, yield and biomass production were reduced as row spacing increased but the amount differed for each genotype. There were no differences in N fixation amongst varieties but row spacing significantly decreased the percent of N fixation (also called %N derived from the atmosphere or %Ndfa) and the total amount of N fixed, particularly at the Dalby site (Table 2).

Up to 59 kg N/ha remained at the Dalby site when chickpeas were grown on 0.25m rows but only 23 kg N/ha from the 1.0 m row spacing. At Goondiwindi, the net N balance ranged from 6 down to -6 kg N/ha as row spacing increased from 0.25m to 1.0m. As a crops' demand for N increased so did the N fixation by that crop as seen at our Dalby trial grown under better seasonal conditions.

Table 2. Reduction in biomass, N fixation (%N derived from the atmosphere or %Ndfa) and total amount of N fixed in chickpea (meaned across 3 genotypes) as row spacing in the field increases.

	Shoot dry weight (t/ha)		%Ndfa		Total crop N fixed (kg/ha)		N balance (kg/ha)	
Row spacing (m)	Dalby	Goondi	Dalby	Goondi	Dalby	Goondi	Dalby	Goondi
0.25	9.89	4.75	61.0	39.2	187.3	62.8	59	6
0.5	9.25	4.23	55.8	33.9	161.9	48.0	45	-5
1.0	7.96	3.59	47.6	35.4	122.5	42.0	23	-6
LSD (P=0.05)	1.12	0.67	7.0	n.s.	31.5	16.3	n.s.	n.s.

Time of sowing

Sowing on time to take full advantage of soil water and growing conditions that maximise crop production can make a significant impact on amount of N fixed. The graph below gives an indication of the impact that time of sowing of soybeans can have on N fixation comparing soybeans planted in the middle of the appropriate planting window with late in that window . Figure 1 show that for two different soybean varieties (NF246-64 and PR443) as much as 150kg/ha less N is fixed due to the shortened growing season. However, increasing the plant population becomes very important for improving the proportion of N that is fixed if time of sowing is delayed.

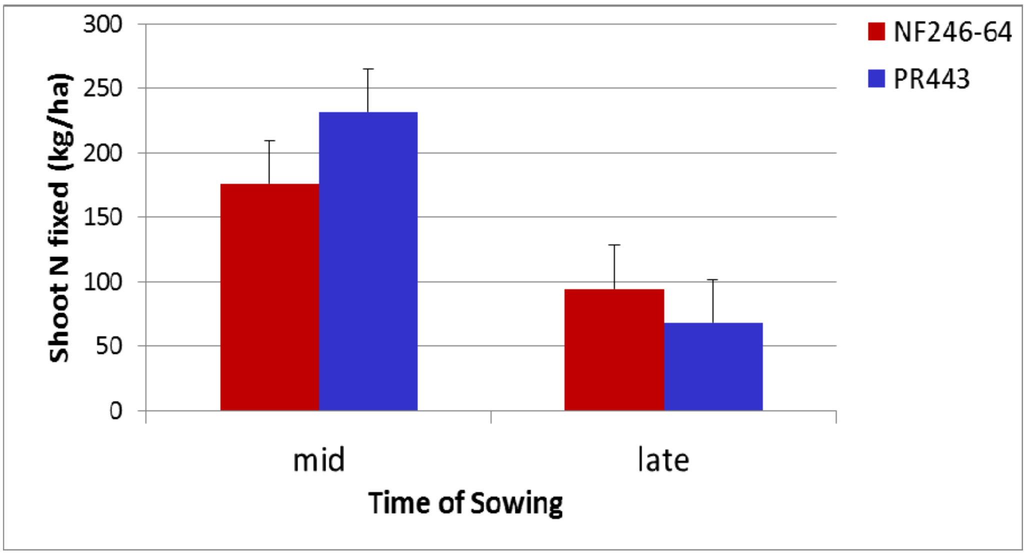

Figure 1. Nitrogen fixation is reduced when soybeans are sown late in the planting window (LSD (5%)= 33.2) .

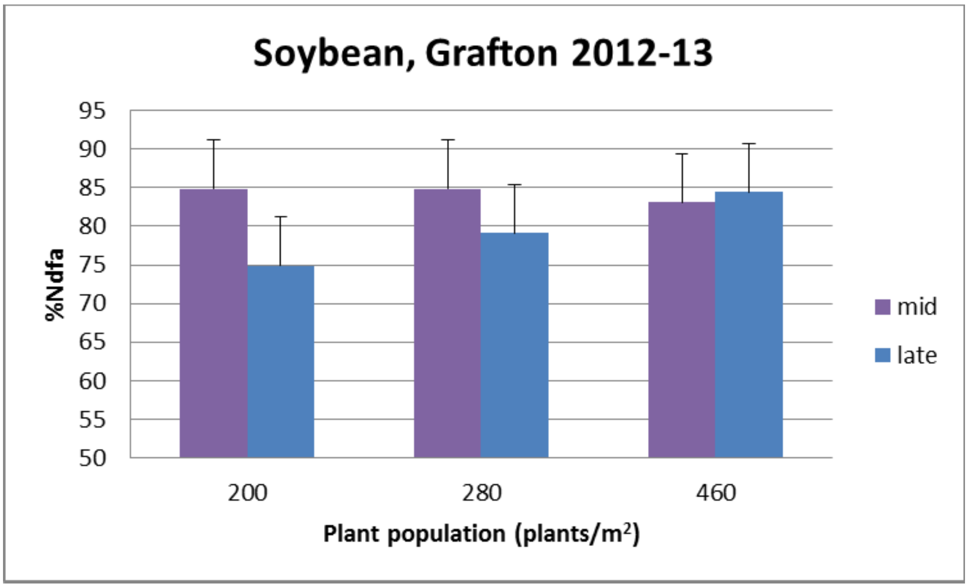

Figure 2. Higher plant populations compensate partially for a later planted soybean crop in terms of N fixation (LSD (5%) = 8.7)

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Update on a dedicated sampling strategy to improve the accuracy of PreDicta B® soil testing to identify crown rot risk

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Key words

DNA soil testing, disease risk, crown rot, root lesion nematodes

GRDC codes

DAS00137 – National improved molecular diagnostics for disease management

DAN00175 – National crown rot epidemiology and management program

Take home messages

- PreDicta B® is a good technique for identifying the level of risk for crown rot (and other soil-borne pathogens) prior to sowing within paddocks. However, this requires a dedicated sampling strategy and IS NOT a simple add on to a soil nutrition test.
- Soil cores should be targeted at the previous winter cereal row if evident and RETAIN any stubble fragments.
- Short pieces of stubble (two from each PreDicta B® soil sampling location) from previous winter cereal crops and/or grass weed residues can be added to the soil sample to enhance detection of the *Fusarium* spp. that cause crown rot.
- 'Spiking' with stubble will reduce the likelihood of 'failure to warn' situations for crown rot but unfortunately will also increase the probability of false warnings.

Introduction

PreDicta B® is a DNA based soil test which detects levels of a range of cereal pathogens that is commercially available to growers through the South Australian Research and Development Institute (SARDI). The main pathogens of interest in the northern grains region detected by PreDicta B® are *Fusarium* spp. (crown rot), *Bipolaris sorokiniana* (common root rot), *Pythium* (damping off) and both *Pratylenchus thornei* and *P. neglectus* (root lesion nematodes, RLNs). Over recent years PreDicta B® has been shown to be a reliable method for assessing RLN populations but is perceived by industry to be less reliable in assessing levels of crown rot risk in the northern region.

Between 2010 and 2012, we conducted an annual winter cereal pathogen survey of 248 paddocks across 12 districts in central and northern NSW. The three-year survey measured the DNA levels of the *Fusarium* pathogen at sowing against the infection levels that had developed by harvest. This research found that in 75% of paddocks, PreDicta B® at sowing predicted the actual level of infection that developed in the crop as measured after harvest within one risk category. In 3% of paddocks PreDicta B® overestimated the risk of infection compared to actual development levels (false warning) but of more concern was that PreDicta B® underestimated the risk of crown rot in 22% of paddocks (failure to warn).

The underestimation of crown rot risk is potentially due to the crown rot fungus being stubble-borne while PreDicta B® is a soil based test. Further investigation found that soil nutrition sampling strategies were often being used to collect both the soil nutrition and PreDicta B® samples. This is significant because soil nutrition samples are normally collected between the rows with stubble removed whereas PreDicta B® samples need to be collected along the row of the previous cereal crop and incorporate any stubble residues.

Improving the accuracy and calibrating PreDicta B® in the northern region for crown rot is important for advisers and growers to better plan their crop and varietal selection prior to winter crop sowing and avoid costly yield losses from this disease. This is particularly relevant leading into the 2015 cropping season with a high durum grain price last season likely to see many growers considering durum this year. Durum is highly susceptible to crown rot so the cost of getting it wrong and sowing into a high disease risk paddock is significant.

The following paper reports on collaborative research conducted by NSW DPI and SARDI across central/northern NSW in 2013 to improve the accuracy of the PreDicta B® test in assessing crown rot risk by fine tuning soil sampling techniques and recommendations.

Detection issue?

Currently there are three separate tests within PreDicta B® that detect common *Fusarium* species causing crown rot across Australia - two tests which detect variations in *F. pseudograminearum* populations and a third test which detects both *F. culmorum* and *F. graminearum* but cannot differentiate between these two species. The failure to warn of the risk of crown rot in 22% of paddocks could be related to the inability of the current PreDicta B® tests to actually detect other species/variants of *Fusarium* causing crown rot across the region. A national survey was conducted in 2013 and 2014 with over 800 *Fusarium* isolates collected from wheat and barley plants with basal browning characteristic of crown rot infection from across Australia. Molecular analysis determined that all *Fusarium* species known to cause crown rot are being detected by the current PreDicta B® assays. Hence, there is no detection issue with the current PreDicta B® tests that could contribute to the underestimation of crown rot risk.

Does the addition of stubble ('spiking') improve PreDicta B® assessment of crown rot risk?

In 2013 each of the six ranges in 13 cereal NVT sites and 8 NSW DPI district pathology (DP) trials were cored using PreDicta B® (Table 1). Two separate soil samples were collected from each range at each of the 21 field sites spread from central NSW up into southern Qld. All cores were targeted at the previous winter cereal rows if evident. Previous winter cereal crop stubble was also collected across each separate range at coring if present and used to spike set soil samples. Twenty-five lowest nodes (1 cm segments around node) were cut from the corresponding stubble sample and added to one of the samples collected from each range. All samples were then sent to SARDI for PreDicta B® analysis.

Table 1. Location of field trial sites in 2013

Site no.	Location	Site No.	Location
1	NVT Bellata	12	NVT Westmar
2	NVT Bullarah	13	NVT Wongarbon
3	NVT Coolah	14	DP Narrabri
4	NVT Coonamble	15	DP Terry Hie Hie
5	NVT Gilgandra	16	DP Bithramere
6	NVT Macalister	17	DP Spring Ridge
7	NVT Merriwa	18	DP Tamworth
8	NVT North Star	19	DP Garah
9	NVT Spring Ridge	20	DP Rowena
10	NVT Trangie	21	DP Macalister
11	NVT Tulloona		

After harvest stubble was collected from all plots of three varieties (EGA Gregoryⓟ, Suntopⓟ and Caparoiⓟ or Spitfireⓟ) at each site. Twenty-five crowns from each plot were trimmed, surface sterilised and plated onto laboratory media to determine the incidence of crown rot infection that developed during the 2013 based on the recover of *Fusarium.*

PreDicta B® risk for crown rot is a sum of all three *Fusarium* tests which are then converted to a log scale to normalise the data. Current PreDicta B® crown rot risk categories for durum wheat are used in the northern region and corresponding harvest infection levels based on plating have also been developed for the region (Table 2).

Table 2. Current PreDicta B® crown rot risk levels and corresponding harvest infection level

PreDicta B® (log *Fusarium* DNA/g soil)	Risk or harvest disease level	Incidence of infection (% *Fusarium* recovery)
<0.6	Below detection limit (BDL)	<2
0.6 – 1.4	Low	3-12
1.4 – 2.0	Medium	13-24
>2.0	High	≥25

Addition of stubble fragments to soil samples was only possible at few sites with previous cereal stubble being present at 7 (red larger diamonds, Figures 1 & 2) of the 21 sites (2, 4, 5, 8, 12, 16 and 18). The addition of stubble increased the crown rot risk level at six of the sites, from low to high at 2 sites (sites 4, NVT Coonamble and 12, NVT Westmar), low to medium at 2 sites (sites 5, NVT Gilgandra and 8, NVT North Star) and medium to high at 2 sites (sites 2, NVT Bullarah and 18, DP Tamworth)(Figure 1 and 2). For the last site (site 16, DP Bithramere) the log *Fusarium* DNA/g increased from 2.5 to 4.3 with the addition of stubble but this did not increase the predicted crown rot risk level as both values represented a high risk of crown rot development.

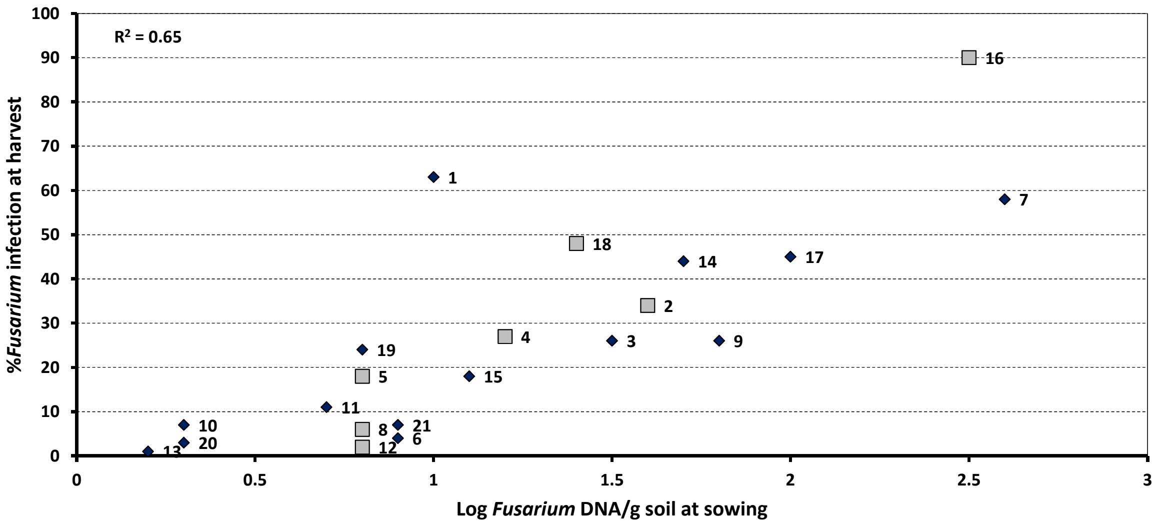

Figure 1. Relationship between at sowing DNA levels of Fusarium using PreDicta B® and incidence of crown rot infection at harvest – 'Unspiked' samples in 2013
Sites spiked with stubble represented by larger grey squares (sites 2, 4, 5, 8, 12, 16 and 18)

There was a 65% correlation between unspiked PreDicta B® results collected at sowing and the actual incidence of crown rot infection that developed by harvest (Figure 1). Fourteen sites in 2013 had a low or BDL risk for crown rot development based on unspiked PreDicta B® soil tests at sowing. At 8 of these sites (6, 8, 10, 11, 12, 13, 20 and 21) the DNA test correctly predicted the actual level of disease which developed while at 6 sites (1, 4, 5, 15, 18 and 19) PreDicta B® underestimated the risk of disease development. This is generally considered a 'failure to warn' and was particularly evident at site 1 (NVT Bellata) where only a 1.0 log *Fusarium* DNA value was measured at sowing but 63% of plants were infected with crown rot at harvest. In the medium risk category the DNA test correctly predicted the incidence of disease development at two sites (3 and 9) but underestimated the risk at two sites (2 and 14). All three sites predicted to be in the high risk category by the DNA test at sowing (sites 7, 16 and 17) did develop high infection levels during the 2013 season (Figure 1).

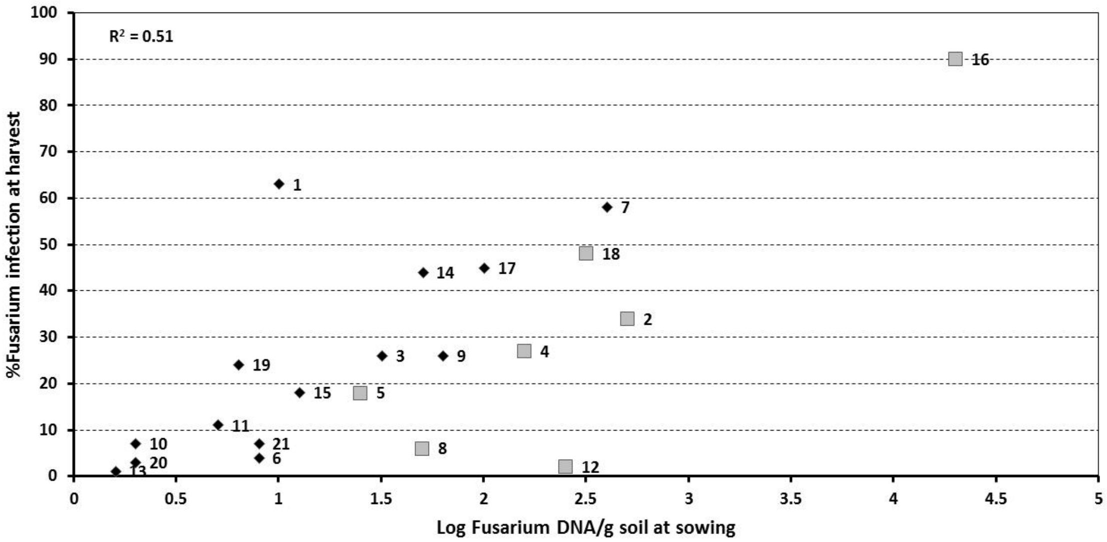

Figure 2. Effect of 'spiked' samples at 7 sites on the relationship between at sowing DNA levels of Fusarium using PreDicta B® and incidence of crown rot infection at harvest – 2013. Sites spiked with stubble represented by larger grey squares (sites 2, 4, 5, 8, 12, 16 and 18)

The addition of stubble to the PreDicta B® soil samples ('spiking') collected from seven of the 21 sites at sowing reduced the correlation with the incidence of plants infected with crown rot at harvest down to 51% (Figure 2). However, spiking with stubble at sites 4, 5 and 18 removed them from the low risk category into their correct level of disease incidence at harvest. That is, these were no longer 'failure to warn' situations, with the stubble spiking correctly predicting the risk at sowing of what developed by harvest in the crop. Stubble spiking also corrected the underestimation of risk from medium to high at site 2. Spiking did not change risk categories at site 16 which was high with both the unspiked and spiked soil samples. However, the higher DNA level in the spiked sample better reflected the higher disease incidence (90%) at this site relative to other sites (max. 63%) in 2013.

Unfortunately, in two situations (sites 8 and 12) spiking led to an overestimation of the crown rot risk at sowing. Spiking pushed site 8 into a medium risk category but only 6% of plants were infected at harvest while site 12 was pushed into a high risk category with only 2% of plants infected at harvest. These situations would be considered false positives and potentially lead to a missed opportunity for growers where they could have grown a winter cereal crop with minimal risk of yield loss from crown rot.

Conclusions

PreDicta B® is a soil based test so with the collection of cores targeted at the previous winter cereal rows it can provide a good measure of *Fusarium* levels in the crowns below ground but is restricted in its ability to detect levels in above ground stubble. Adding stubble ('spiking') is likely to increase the overestimation of crown rot risk (false positives) while reducing the likelihood of underestimation or 'failure to warn' which we consider a preferred situation for growers.

The addition of stubble is also likely to reduce sampling issues following wetter summers (e.g. some northern regions in 2014/15) which can result in greater survival of *Fusarium* in above ground residues. Significant summer rainfall can lead to rapid decomposition of the crowns of previous cereal crops below ground which reduces the survival of *Fusarium* in this tissue. However, standing stubble dries out relatively quickly following rainfall events and can hence harbour crown rot inoculum for an extended period. Soil sampling, even targeted at the previous cereal row, will only detect *Fusarium* levels in the crowns. Hence, the addition of stubble to PreDicta B® soil tests will compensate for situations where there is still significant survival of *Fusarium* in above ground residues.

Recent collaborative research in the northern region between SARDI and NSW DPI has demonstrated that use of a smaller diameter (1 cm) soil core (e.g. Accucore) to collect 30-45 cores (depending on sampling depth) targeted at the previous cereal row if evident provides a good measure of both RLN and crown rot risk along with a range of other pathogens. This number of cores collected spatially across the paddock is required to account for the potential variability in the distribution of crown rot inoculum.

This research was continued across further sites in the northern region in 2014 and expanded to around 160 NVT sites nationally. This will facilitate further refinement of sampling strategies and calibrate risk categories across regions.

Recommended PreDicta B® sampling strategy for crown rot

These findings have resulted in amended sampling strategy recommendations to improve the value of PreDicta B® as a management tool for crown rot. To correctly sample, growers and advisors should:

- Collect three cores of 1 cm diameter and 15 cm deep from each of 15 different locations within the target paddock or production zone. Samples may be taken to 30 cm depth in the northern region if concerned about *Pratylenchus thornei* detection. If using a larger diameter core or coring to 30 cm, take fewer cores per location.
- Take the soil cores from along/in the rows of previous cereal crop if still visible and retain any stubble collected by the core (most soil borne pathogens are concentrated under the rows of the last cereal). Sampling depth (0-15 cm or 0-30 cm) does not appear to greatly impact on detection of the various pathogen levels in the northern region when the collection of cores is targeted at the previous cereal rows. However, the actual sampling depth needs to be recorded on the sample bag when collected as it is used to refine reporting of results to adjust for pathogens which are more concentrated at the soil surface.
- If the rows cannot be seen, take the cores at random.
- Add two piece of cereal stubble (if present) to the sample bag at each of the 15 sampling locations to improve the detection of crown rot. Each piece should be a single dominant tiller from the base of different plants and include the crown to the first node (discard material from above the first node).
- The maximum sample weight should not exceed 500 g.
- Significant stubble disturbance such as through harrowing, cultivation or mulching increases the risk of crown rot development if the stubble is infected with *Fusarium* and collection of soil samples prior to stubble disturbance is likely to underestimate the crown rot risk.

Acknowledgments

This project was co-funded by NSW DPI, SARDI and GRDC under the national improved molecular diagnostics for disease management project (DAS00137) and the national crown rot epidemiology and management program (DAN00175). Assistance provided by Robyn Shapland, Finn Fensbo, Patrick Mortell, Kay Warren, Tara Burns and Karen Cassin (NSW DPI); Herdina, Russell Burns, Aidan Thomson, Ina Dumitrescu, Danuta Pounsett, Irena Dadej, Daniele Giblot-Ducray (SARDI); and Diane Hartley (CSIRO) is greatly appreciated.

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Crown rot: an update on latest research

Steven Simpfendorfer, NSW DPI Tamworth

Key words

Stored soil water, inoculum, PreDicta B, yield loss, variety tolerance, root lesion nematodes

GRDC code

DAN00175: National crown rot epidemiology and management program

Take home messages

- Impact of crown rot on yield and quality is a balance between inoculum levels and soil water
- The balance is heavily tipped towards soil water yet most management strategies tend to focus solely on combating inoculum, sometimes to the detriment of soil water
- Cultivation (even shallow) distributes infected residue more evenly across paddocks and into the infection zones below ground for crown rot. This IS NOT good!
- Some of the newer wheat varieties appear promising in that they provide improved tolerance to crown rot
- PreDicta B is a good technique for identifying the level of risk for crown rot (and other soil-borne pathogens) prior to sowing within paddocks. However, this requires a dedicated sampling strategy and IS NOT a simple add on to a soil nutrition test

Introduction

Crown rot, caused predominantly by the fungus *Fusarium pseudograminearum* is a significant disease of winter cereals in the northern region. Infection is characterised by a light honey-brown to dark brown discolouration of the base of infected tillers, while major yield loss from the production of whiteheads is related to moisture stress post-flowering. It is critical that growers understand that there are three distinct and separate phases of crown rot, namely ***survival, infection*** and ***expression.*** Management strategies can differentially effect each phase.

Survival: the crown rot fungus survives as mycelium (cottony growth) inside winter cereal (wheat, barley, durum, triticale and oats) and grass weed residues, which it has infected. The crown rot fungus will survive as **inoculum** inside the stubble for as long as it remains intact, which varies greatly with soil and weather conditions as decomposition is a *very slow* process.

Infection: given some level of soil moisture the crown rot fungus grows out of stubble residues and infects new winter cereal plants through the coleoptile, sub-crown internode or crown tissue which are all below the soil surface. The fungus can also infect plants above ground *right at* the soil surface through the outer leaf sheathes. However, with all points of infection, direct contact with the previously infected residues is required and infections can occur throughout the whole season given moisture. Hence, wet seasons favour increased infection events by the crown rot fungus when combined with the production of greater stubble loads significantly builds-up inoculum levels.

Expression: Yield loss is related to moisture/temperature stress around flowering and through grain-fill. This stress is believed to trigger the crown rot fungus to proliferate in the base of infected tillers, restricting water movement from the roots through the stems, and producing whiteheads that contain either no grain or lightweight shrivelled grain. The **expression** of whiteheads in plants infected with crown rot (i.e. still have basal browning) is restricted in wet seasons and increases greatly with increasing moisture/temperature stress during grain-fill. Focus attention to crops around trees within a paddock or along tree lines. Even in good years whiteheads associated with crown rot infection are likely to be seen around trees. This is due to the extra competition for water.

How to manage crown rot

Crop rotation

The most effective way to reduce crown rot inoculum is to include non-susceptible crops in the rotation sequence. The crown rot fungus can survive for two to three years in stubble and soil. Growing a non-host crop for at least two seasons is recommended to reduce inoculum levels. This allows time for decomposition of winter cereal residues that host the crown rot fungus. Stubble decomposition varies with the type of break crop grown – their canopy density and rate of the canopy closure as well as row spacing, the amount of soil water they use and seasonal rainfall. **Trials in the northern region have indicated that faba beans and canola are better break crops for crown rot than chickpeas.**

Cultivation

Growers may cultivate their stubble for a range of reasons e.g. to reduce trash load prior to sowing. However, the effect of cultivation on crown rot is complex as it potentially impacts on all three phases of the disease cycle.

Survival: stubble decomposition is a microbial process driven by temperature and moisture. Cultivating stubble in theory increases the rate of decomposition as it reduces particle size of stubble, buries these particles in the soil where microbial activity is greater and the soil environment maintains more optimal moisture and temperature conditions compared to the soil surface or above ground. However, cultivation also dries out the soil in the cultivation layer, which immediately limits the potential for decomposition of the incorporated stubble. Decomposition of cereal stubbles is a *very slow* process that requires adequate moisture for an extended period of time to occur completely. A summer fallow (even if extremely wet and stubble has been cultivated) is **not** long enough!

Infection: as covered earlier, the majority of infection sites with crown rot are below ground and physical contact between an infected piece of residue and these plant parts is required to initiate infection. Cultivation of winter cereal stubble harbouring the crown rot fungus effectively breaks the inoculum into smaller pieces and spreads them more evenly through the cultivation layer across the paddock. Consequently, the crown rot fungus has been given a much greater chance of coming into contact with the major infection sites below ground as the next winter cereal crop germinates and develops. In a no-till system the crown rot fungus becomes confined to the previous cereal rows and is more reliant on infection through the outer leaf sheathes at the soil surface. This is why inter-row sowing with GPS guidance has been shown to provide around a 50% reduction in the number of plants infected with crown rot when used in a no-till cropping system. Cultivation or harrowing negates the option of inter-row sowing as a crown rot management strategy.

Expression: extensive research has shown that cultivation dries out the soil to the depth of cultivation and reduces the water infiltration rate due to the loss of structure (macropores etc). The lack of cereal stubble cover can also increase soil evaporation. With poorer infiltration and higher evaporation, fallow efficiency is reduced for cultivated systems compared to a no-till stubble retention system. Greater moisture availability has the potential to provide buffering against crown rot expression late in the season. Like crown rot management and all farming practices, cultivation is a balancing act between perceived benefits and costs.

Stubble burning

Burning removes the above ground portion of crown rot inoculum but the fungus will still survive in infected crown tissue below ground so it is **not** a 'quick fix' for high inoculum situations. Removal of stubble through burning will increase evaporation from the soil surface and impact on fallow efficiency. A 'cooler' autumn burn is therefore preferable to an earlier 'hotter' burn as it minimises the negative impacts on soil moisture storage whilst still reducing inoculum levels.

Reduce water loss

Inoculum level is important in limiting the potential for yield loss from crown rot but the overriding factor dictating the extent of yield loss is moisture/temperature stress during grain-fill. Any management strategy that limits storage of soil water or creates constraints that reduce the ability of roots to access this water will increase the probability and/or severity of moisture stress during grain-fill and exacerbate the impact of crown rot.

Grass weed management

Grass weeds should be controlled in fallow periods and in-crop, especially in break crops, as they host the crown rot fungus and can also significantly reduce soil moisture storage. In pasture situations grasses need to be cleaned out well in advance of a following cereal crop as they serve as a host for the crown rot fungus.

Row placement

In a no-till system the crown rot fungus becomes confined to the previous cereal rows and is more reliant on infection through the outer leaf sheathes at the soil surface. This is why inter-row sowing with GPS guidance has been shown to provide around a 50% reduction in the number of plants infected with crown rot when used in a no-till cropping system. Further research conducted by NSW DPI has also demonstrated the benefits of row placement in combination with crop rotation and the relative placement of break crop rows and winter cereal rows within the sequence to limit disease and maximise yield (Verrell 2014 GRDC Updates). Sowing break crops between standing wheat rows which are kept intact then sowing the following wheat crop directly over the row of the previous years break crop ensures 4 years between wheat rows being sown in the same row space. This substantially reduces the incidence of crown rot in wheat crops, improves establishment of break crops (esp. canola) and chickpeas will benefit from reduced virus incidence in standing wheat stubble.

Soil type

Soil type does not differentially affect the survival or infection phases of crown rot. However, the inherent water holding capacity of each soil type interacts with expression by potentially buffering against moisture stress late in the season. Hence, yield loss can be worse on red soils compared to black soils due to their generally lower water holding capacities. Any other sub-soil constraint e.g. sodicity, salinity or shallower soil depth effectively reduces the level of plant available water which can increase the expression of crown rot.

Cereal crop and variety choice

All winter cereal crops host the crown rot fungus. Yield loss varies between crops and the approximate order of increasing loss is oats, barley, triticale, bread wheat and durum.
Barley is very susceptible to crown rot infection and will build up inoculum but tends to suffer reduced yield loss through its earlier maturity relative to wheat. Late planted barley can still suffer significant yield loss especially when early stress occurs within the growing season.
Bread wheat varieties appear to differ significantly in their level of yield loss to crown rot with newer varieties in the northern region (Sunguard⦇, Suntop⦇, LRPB Spitfire⦇, LRPB Lancer⦇ and Mitch⦇) appearing to suffer less yield impacts compared to the widely grown EGA Gregory. NSW DPI trials from a total of 23 sites in 2013/14 conducted across the northern region indicate that this can represent a yield benefit of around 0.50 t/ha in the presence of high levels of crown rot infection.

However, **variety choice is NOT a solution to crown rot** with even the best variety still suffering up to 40% yield loss from crown rot under high infection levels and a dry/hot seasonal finish. All current durum varieties are very susceptible to crown rot and should be avoided in medium and high risk situations.

Sowing time

Earlier sowing within the recommended window of a given variety for a region can bring the grain-fill period forward and reduce the probability of moisture and temperature stress during grain-fill. Earlier sowing can increase root length/depth and provide greater access to deeper soil water later in the season, which buffers against crown rot expression. This has been shown in previous NSW DPI research across seasons to reduce yield loss from crown rot. Earlier sowing however can place a crop at risk of frost damage during its most susceptible time. Sowing time in the northern region is a balancing act between the risk of frost and heat stress. However, when it comes to crown rot, increased disease expression with delayed sowing can have just as big an impact on yield as frost. The big difference from NSW DPI trial work is the additional detrimental impact of later sowing on grain size in the presence of crown rot infection.

Interaction with root lesion nematodes

Root lesion nematodes (RLNs) are also a wide spread constraint to wheat production across the region. Two important species of RLN exist throughout the northern region, namely *Pratylenchus thornei* (*Pt*) and *P. neglectus* (*Pn*). Previous surveys of the northern NSW have found that *Pt* is more widespread and generally at higher populations than *Pn.* RLNs feed inside the root systems of susceptible winter cereals creating lesions and reducing lateral branching. This reduced the efficacy of the root system to extract soil water and nutrients which subsequently can exacerbate the expression of crown rot. Varieties with reduced tolerance of *Pt* can suffer significantly greater yield loss from crown rot if both of these pathogens are present within a paddock.

How do I know my level of risk for crown rot and RLN?

PreDicta B is a DNA based soil test which detects levels of a range of cereal pathogens that is commercially available to growers through the South Australian Research and Development Institute (SARDI). Because the crown rot fungus is stubble-borne, normal soil samples are unreliable and disease detection is highly sensitive to the sampling technique used. Follow the specific protocols for how to collect samples for crown rot testing (further paper in these proceedings).

If you are not willing to follow the recommended PreDicta B sampling strategy then DO NOT assesses disease risk levels prior to sowing.

Further reading

GRDC Grains Research Update paper (July 2014) on Managing crown-rot through crop sequencing and row placement, Andrew Verrell, NSW DPI

Acknowledgments

This paper includes some older information conducted in collaboration with Northern Growers Alliance as acknowledged in the text and crop sequences in combination with row placement research was conducted by Dr Andew Verrell (NSW DPI). This information has been presented in greater detail at previous GRDC Updates with full reports available at www.grdc.com.au. Technical assistance provided by Robyn Shapland, Finn Fensbo, Karen Cassin, Kay Warren, Rod Bambach, Peter Formann, Stephen Morphett and Jim Perfrement are gratefully acknowledged.

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support. The project is co-funded by the NSW state government through the NSW DPI who are also thanked for their support in fully funding the position of Dr Simpfendorfer and laboratory and other infrastructure costs.

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Get the first, second and third punch in on feathertop Rhodes grass! Which strategies are working best?

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[1] Independent Consultants Australia Network (ICAN)
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Key words

Feathertop Rhodes grass, *Chloris virgata*

GRDC code

ICN00016 & NGA00003

Take home message

Commitment to two summers of 100% control of feathertop Rhodes grass should exhaust the seed bank in the soil.

Control strategies are likely to require an integrated approach that includes tillage, crop selection, maximising crop competition, residual herbicides and selective use of double knock applications in fallow.

Feathertop Rhodes (*Chloris virgata*) grass continues to be a major problem weed in zero till farming systems in the northern grains region, with populations continuing to expand further south, particularly along road corridors.

Agronomic factors that influence control strategies

Feathertop Rhodes grass is often the first weed to establish on bare ground following a rainfall event in spring/summer. Studies by Queensland Department of Agriculture and Fisheries showed that feathertop Rhodes would germinate following as little as a 10mm simulated rainfall event, with peak germination occurring at 2 days under a 30°C/20°C day/night environment or 3 days under a 25/15 environment. This was faster than barnyard grass, sowthistle and fleabane which were also included in this study. The broadleaf weeds also required a substantially higher rainfall event to initiate germination. This highlights that feathertop Rhodes is likely to the first weed to germinate and establish following spring storms.

Feathertop Rhodes is a surface germinator, with practically no germination occurring from seed below the top 2cm in the soil.

Seed persistence is short. Viability of seed declines rapidly and almost no seed remains viable 12 months after shedding. This can be utilised as the proverbial boxer's 'glass jaw' in management of feathertop Rhodes – a concerted effort over two consecutive summers to completely stop seed set and any further recruitment into the paddock can see paddocks rapidly go from infested to effectively no feathertop Rhodes grass, in a couple of years.

Unlike most other weeds, studies have shown that burying seed does not increase persistence. This also opens up opportunities for management where cultivation is an option.

Feathertop Rhodes is a prolific seeder, with an individual plant producing up to 6000 viable seeds under good growing conditions. However when plants are under moisture stress, they will quickly begin setting viable seed, even when the plant is small/young.

Feathertop Rhodes grass does not compete well against existing grass or pasture. However it often is the dominant species in any bare areas (e.g. roads, fallow) right up against the edge of the crop and pasture paddocks.

These factors see FTR quickly dominate bare earth roadsides or zero till paddocks, especially following wet summers where control programs have not been able to stop seed set and recruitment into the seed bank.

Imazapyr (e.g. Arsenal®) based herbicides are registered for use in non-crop areas to provide residual control.

The first punch – prevention is better than cure

Control of established populations of large feathertop Rhodes is difficult, extremely costly and most likely to be incompatible with zero till farming. Therefore growers should seek to keep FTR out of farming paddocks wherever possible, and urgently seek to remove individual plants before they have a chance to set seed.

Seed can be blown into paddocks from adjacent paddocks, roadways and fencelines where knockdown herbicides have been used to keep these free of vegetation and feathertop is the surviving species. Or seeds may be deposited in the paddock via livestock or machinery or flood water. Typically a single plant in year 1 will result in a small clump covering maybe 2-3m^2 in year 2. Over coming years these patches will continue to expand, potentially seeing the whole paddock infested if nothing is done to stop seed set.

Growers should be continually on the lookout for individual plants and act quickly to manually remove or spot spray these before they are allowed to set seed. Small patches should be chipped, burnt or cultivated to prevent spread. Ideally these should be GPS mapped for future monitoring with a residual herbicide applied prior to the commencement of spring rainfall events.

The second punch – Knockdown herbicides

The use of glyphosate alone cannot be expected to achieve control. Even when using a double knock of glyphosate followed by paraquat under ideal conditions and targeting seedlings before they start tillering, control is variable and rarely provides a commercially acceptable result.

Targeting larger weeds that have commenced tillering, or are under any stress, will typically achieve less than 50% control as a double knock, and often not significantly better than using paraquat alone as a single application.

Glyphosate is not registered for control of feathertop Rhodes grass.

Research trials have shown that Group A herbicides can be effective in providing useful control.

Currently there is a permit (PER12941 expires 31 August 2016) in place in Queensland to permit the use of haloxyfop (e.g. Verdict®) against feathertop Rhodes grass in fallow, prior to planting mungbeans. This must be followed with a double knock of paraquat and should only be applied to weeds at 3-leaf to early tillering growth stage.

The importance of weed growth stage is critical for the performance of Group A herbicides. As weed size increases, translocation of the herbicide reduces throughout the plant. Once plants move from vegetative production to reproductive growth, production of the enzyme targeted by the Group A herbicide reduces in the plant. Further information explaining this can be found in the GRDC Fact Sheet 'Group A Herbicides in Fallow'. http://www.grdc.com.au/GRDC-FS-GroupAinFallow

Figure 1 below presents a summary of 6 trials targeting various sizes of feathertop Rhodes grass at the two application rates covered by the permit, with and without the double knock of paraquat. As can be seen from this analysis, no treatment consistently gave 100% control, however these results clearly demonstrate why the permit requires application on small seedlings (3-leaf to early tiller).

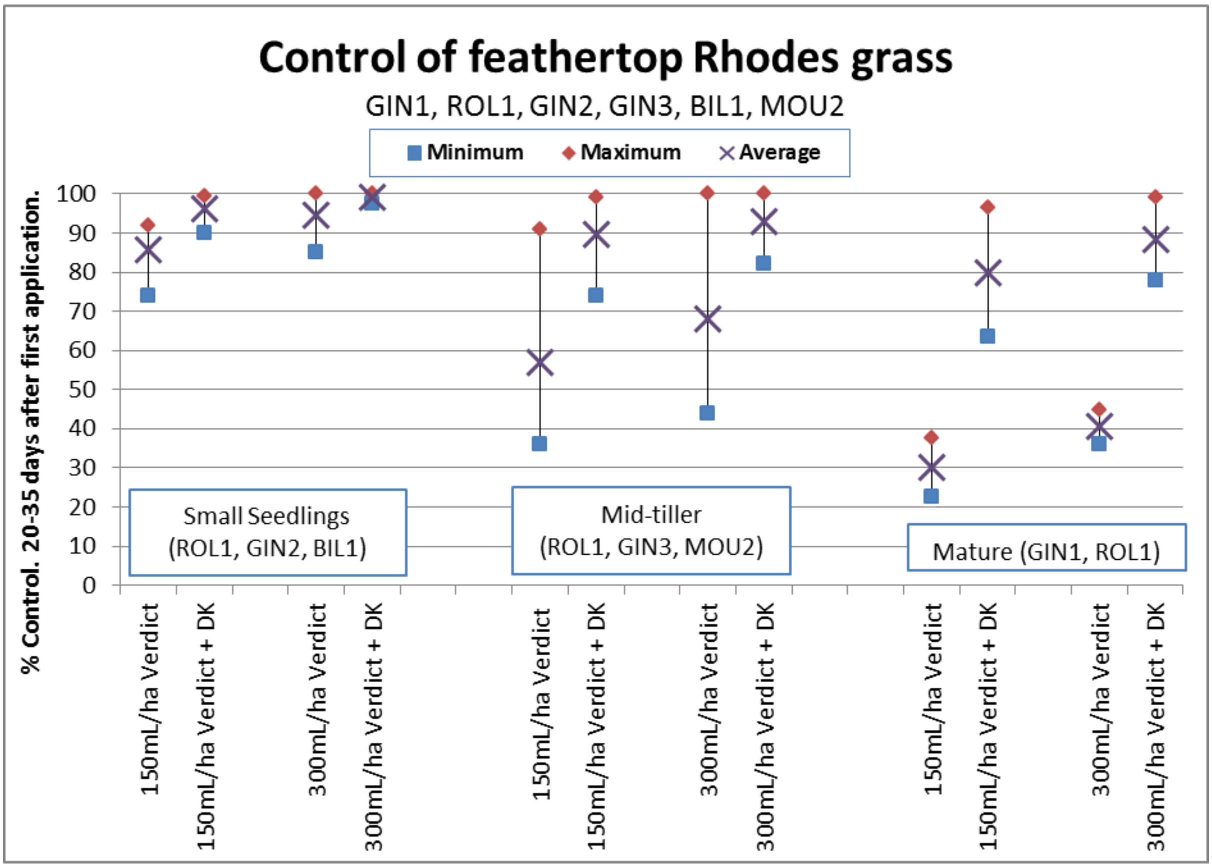

Figure 1. Control of feathertop Rhodes grass at different weed growth stages by 150 and 300 mL/ha Verdict 520, followed by paraquat double knock (DK). Source: Central Queensland Grower Solutions Project 2011/12

Experience has shown that Group A herbicides are one of the quickest modes of action to select for resistance as there is typically a high frequency of resistant individuals in the natural population.

For this reason, all Group A applications applied under permit targeting use in fallow must be followed by a double knock; they should only be targeted at small weeds; and should not be used more than once per season.

It is essential that this mode of action is protected from resistance selection. Group A herbicides are the mainstay of post-emergent grass weed control in summer broadleaf crops.

The third punch – Tactical cultivation

Where feathertop Rhodes grass has got out of hand, and established plants are present, it is likely that tillage will be needed to remove existing weeds.

It is unlikely that any herbicide treatment will provide cost-effective control of mature plants. Where old, established plants remain from last summer they can frequently shade herbicide application, thus leading to unsatisfactory results from subsequent knockdown or residual herbicide applications.

Removing mature plants via cultivation can be very effective. Burial of seed below 5cm prevents germination and this seed will lose viability within about 12 months (providing it is not subsequently returned to the soil surface by further tillage).

While an effective cultivation may bury the vast majority of seed, there is always a small percentage of seed remaining at the soil surface in the preferred germination zone. If something is not done to prevent these seeds from germinating and establishing then the cycle commences again.

A plan should be in place to manage these subsequent germinations via either knockdown or residual herbicides or further tillage.

The knockout blow – Residual herbicides

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

Balance® can be a particularly effective option for fallow management. In addition to residual control of feathertop Rhodes, it will also control fleabane and sowthistle and provide suppression of barnyard grass. Other herbicides used to provide residual control of barnyard grass in a range of situations (e.g. Dual® Gold, Flame®, Balance®, Treflan® and Stomp®) have been noted to reduce germinations of feathertop Rhodes grass.

Going the full ten rounds – Pulling it all together

Where there has been a 'blow out' and a paddock has become infested with feathertop Rhodes it is likely that a management strategy will look something like the following:

- Cultivation of established plants (before seed has been shed).
- Residual herbicide applied if there is still the possibility of further germination before winter.
- Decide on your strategy for summer before the first spring rainfall event, and potential weed germination
    - If fallowing over summer, apply a residual herbicide before spring rainfall. Monitor frequently for any escapes or breakdown of the residual herbicide. Access to an optical (camera) sprayer can be beneficial in cost effectively treating isolated escapes. If the residual treatment has broken down, a double knock application will be required, with consideration given to including another residual application with the second knock.
    - Where soil moisture is adequate, consider a summer broadleaf crop (or cotton where suitable). Use a pre-emergent herbicide effective on grass weeds; keep row spacing narrow and plant population high to increase the benefit of crop competition; and utilise a selective Group A 'fop' herbicide in-crop to control any escapes. This strategy should provide the best defence against feathertop Rhodes over summer.
- Do not plant sorghum or maize into paddocks with a high seed bank population. Pre-emergent herbicide options such as metolachlor are unlikely to provide full season residual control, even at the highest application rate – especially in wet seasons. Late season germinations can establish after the pre-emergent herbicide has broken down.
- If no feathertop Rhodes was allowed to set seed, then seed bank viability should be low the following year. Continue vigilant management for another season to ensure depletion of the seed bank.

Unfortunately the best management strategies for this difficult to manage weed place great reliance on herbicides; and therefore selection of resistant individuals. Glyphosate is ineffective and Group A herbicides are known to be of significant risk of rapid selection for resistance. While there is currently negligible resistance in the northern grains region to many of the pre-emergent herbicides with efficacy on this weed, one thing we have learnt from history is that if we over-rely on a particular herbicide or herbicide group and don't stop weed seed set of survivors, then we will break it.

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Integrating camera sprayers into summer fallow: strategy and farmer experience

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Notes

The what, where and why of soil testing in the northern region

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Take home message

Soil testing is a key component of ensuring both sustainable land management in the longer term and maximising the chance of reaching the water-limited yield potential in the coming season. The sampling strategy adopted will be determined by the reason for sampling (fertility monitoring or fertilizer diagnosis), the size and availability of the different pools nutrient in the soil (determining the appropriate laboratory test method), the mobility of the nutrients of concern in the soil profile (determining soil layers of interest) and the root activity of different rotation species in that soil type-seasonal rainfall combination.

The correct soil sampling strategy and diagnosis of potential nutrient limitations will not guarantee an economic response to applied fertilizer, as seasonal conditions and inappropriate application strategy (timing or placement) can reduce the crop nutrient requirement or limit crop recovery of the applied nutrient. However, it will ensure the best possible chance of delivering on water-limited yield potential in the coming season and represents value for money in a farm management plan.

This paper discusses current thinking on soil sampling methodology (frequency, depth intervals), analytical methods and interpretation relative to fertilizer N responsiveness for the northern grains region.

Perhaps the most compelling argument for soil testing is that if you don't understand the fertility status of the soils under management it is extremely difficult and time-consuming to then ensure the right fertilizer product, application rate, and method of application are used to maximise chances of crop recovery and an economic yield response. This is becoming increasingly important in the northern region as the native fertility levels in our once-fertile clay soils are diminished through grain removal and we become increasingly reliant on external nutrient inputs.

Northern soils and climate

We have some clear advantages in our region over other rain-fed cropping zones. Firstly, moisture stored in the soil profile during a fallow can deliver a significant proportion of our annual crop growth and yield (especially in winter cropping), so once we make a planting decision the questions about crop size (and hence nutrient demand) are more about how much *extra* growth/yield we may derive from the seasonal forecast of in-crop rainfall rather than whether we will have any crop at all. Secondly, for expensive nutrients like phosphorus (P) and potassium (K), we find these nutrients have an excellent residual value for seasons following the actual application, so we have flexibility to apply these nutrients when our cash flow and seasonal/stubble conditions suit, rather than for each crop. Clearly once we understand the soil status of these nutrients, the different crop species nutrient requirements and the rates of crop removal in harvested produce, we can effectively use nutrient budgeting (fertilizer applied - grain removal) to guide our fertility strategy.

However our heavier soil types also confer some disadvantages, and these relate to the typically mobile nutrients like nitrogen (N – our largest and most expensive nutrient input) and sulphur (S).

These nutrients are less mobile in clay soils, and while that means they are less likely to be lost below the root zone by leaching, they are also slower/require higher amounts of rainfall to redistribute into subsoils where much of crop root activity (water and nutrient uptake) occurs. In the case of N, this slow movement into the profile also increases the risk window for significant losses to the atmosphere as a gas through the processes of denitrification and volatilization. These processes predominantly occur at or near the soil surface, although in the case of denitrification, can also extend to deeper layers under prolonged wet conditions. These loss pathways can result in significant losses of plant-available N and so shift the soil nutrient status out of the normal expected range, with implications for fertilizer requirement in subsequent crop seasons. The only practical way to assess the outcome of 'unusual' rainfall events/seasonal conditions for these nutrients is soil testing.

Soil testing strategies

Soils can be tested for a range of factors - to estimate how much water can be or has been stored; to identify the depth of root barriers or subsoil constraints such as boron or salinity; or the potential occurrence of a soil-borne disease. In this paper we focus on soil testing in relation to crop nutrition. This testing can be undertaken to either monitor long term fertility trends in cropped fields (i.e. is my fertilizer strategy maintaining my soil available nutrient status, and are these still appropriate to address yield limitations) or to identify the fertilizer requirement for the coming season. The field sampling strategies to address these two objectives are quite different. The first is quite challenging in trying to quantify changes in nutrient status over time, through repeated sampling at the same and at the same (or similar) reference points, to minimize background variability. The second and most commonly applied approach is trying to adequately represent the fertility status across the management unit in question, be it a yield zone, soil type or paddock..

The frequency with which this sampling should be undertaken will be related to the nutrient status of the field (are levels marginal/limiting or is there good background fertility?) and also how quickly the nutrient status can change (in response to crop uptake and removal, or to rainfall events/seasonal conditions). It is important to remember that when interpreting soil test results the values on the report are (i) only as good as the paddock sampling strategy with which they were collected, (ii) have variability associated with the laboratory analysis and detection method, and (iii) are being related to a critical range of soil test values below which a crop response is expected. In other words, normal soil test results should be used as a guide rather than a guarantee, but will still provide a very firm plank in a sensible nutrient management program. Ideally, integrating plant tissue analysis also would provide a more robust assessment of the soil fertility status.

Sampling depths will vary with the nutrient and reflect the zones in the soil profile contributing to meeting crop demands. The most common soil sampling depth for nutrient analysis has been 0 to 10 centimetres for broad-acre crops. This layer was chosen because nutrients, especially P, and plant roots in early growth stages are more concentrated within this layer. However to obtain more comprehensive soil nutrient data, sampling below 10cm should be considered for some nutrients.

Suggested sampling increments for key nutrients (and salinity/sodicity constraints) for northern cropping regions are:

- 0 to 10cm (N, P, K,S and sodicity);
- 10 to 30cm (N, P, K and S);
- 30 to 60cm (N and S, salinity/sodicity);
- 60 to 90cm (N, salinity/sodicity); and
- 90 to 120cm (optional - N, salinity/sodicity).

Deeper sampling does raise issues of logistics and cost, which should be discussed with soil test providers. However, the additional information provides a clearer insight into nutrient status in the crop root zone. Changes in level of nutrient availability or subsoil constraint are very slow so the frequency with which these need to be measured also has longer time scale, amortizing the cost out over many years.

Analytical results and testing methods

Soil test information is most useful for indicating the available amounts of macro-nutrients (those required in relatively large amounts to sustain plant growth – N, P, K, and S, calcium [Ca], magnesium [Mg] and sodium [Na]). Results for micro-nutrients (zinc, copper, manganese, boron) are also useful, but much more as a broad indicator of soil status rather than being directly linked to crop requirements and likely fertilizer response. Tissue testing for micronutrients is typically more informative for plant requirement in that regard.

Appropriate soil tests for measuring soil extractable or plant available nutrients in the northern cropping region are:

- Bicarbonate extractable P (Colwell-P), to assess easily available soil P;
- Acid extractable P (BSES-P), to assess slower release soil P reserves and the build-up of fertiliser residues;
- Exchangeable K;
- KCl-40 extractable S or MCP-S; and
- 2M KCl extractable mineral N, to provide measurement of nitrate-N and ammonium-N.

Tests for N and S provide information on nutrient supply (i.e. they can be directly linked to the quantity of nutrient available to the crop), while P and K tests indicate nutrient sufficiency/deficiency. It should be noted that N (and to a lesser extent S) demand is highly influenced by seasonal conditions, mineralisation from crop residues and soil organic matter between testing and harvest, and crop yield potential, making soil testing for N in isolation an unreliable indicator of fertiliser N requirements.

Other measurements that aid the interpretation of soil nutrient tests include:

- Soil carbon/organic matter content;
- Phosphorus buffering index (PBI);
- Soil salinity measured as electrical conductivity; and
- Chloride and other exchangeable cations (Ca, Mg and Na) including aluminium.

Further details of these analytical methods can be found in the Crop Nutrition factsheet for the northern grains region (http://grdc.com.au/Resources/Factsheets/2014/01/Soil-testing-for-crop-nutrition-North)

Frequency of testing

The frequency of soil testing in a field will be determined by the size of the available nutrient pool, the mobility of each nutrient in soil water and the rates of crop uptake and removal. The availability of nutrients which are accumulated and removed in large quantities (e.g. N), or which are subject to significant loss pathways (gaseous or leaching losses) can change quite quickly, and so will require closer attention. This may include regular soil testing, but under a string of similar climatic conditions, use of a nutrient budgeting approach combined with periodic soil testing can provide satisfactory results. However, as indicated by the problems with N availability after the La Nina years in 2010-2012, once anomalous events occur a soil test re-set is required to quantify the impact and identify the need to change the management approach.

Other nutrients taken up in large quantities but not necessarily removed in grain (e.g. K), and which are not mobile in the soil water, can change their distribution down a soil profile quite quickly, concentrating in shallow topsoil layers. Minimum or no-till management accentuates this nutrient 'stratification' so monitoring to detect such changes and develop a management response can be required relatively frequently in soils where (particularly subsoil) nutrient status is marginal.

Noting these exceptions, some general comments about frequency can be considered. Nutrient status in the top 10cm can typically change the fastest due to high root densities, stubble/residue return and fertilizer placement. As a result, these layers are typically sampled with greatest frequency. With the exception of mobile and dynamic nutrients like N, changes in status in deeper layers will be slower, especially in relation to immobile nutrients like P, K and micro-nutrients, and so will require less frequent testing. However an important point is that knowledge about the subsoil nutrient status of each paddock, especially in relation to slow release nutrient pools like BSES-P and limits to root activity like salinity, are essential to allow development of an effective fertilizer management program.

Relating soil test results to likely fertilizer responses

This topic was covered by Chris Guppy in some detail in the 2012 Goondiwindi Updates, and a detailed research program to improve our understanding of the critical soil test ranges below which crop response to applied fertilizer would be expected has been undertaken since then in UQ00063 (PKS in all crops) and UQ00066 (N in sorghum and canola). This work was based on the realization that most attention had been applied to wheat (N responses and the need for starter P based on the 0-10cm layer), with few guidelines for other crops. In the following section we show new information on the relationship between soil test and fertilizer N responsiveness (expressed as % maximum yield with applied N) for sorghum derived under UQ00066, and note that similar relationships have not yet been able to be developed for canola.

We also update (or in some cases simply reproduce) the indicative estimates of critical soil test ranges for P and K reported by Chris Guppy in 2012, and note that results from UQ00063 have yet to resolve the uncertainty around the ability of soil tests to predict responses to applied S – even in a supposedly responsive crop like canola.

Soil test N response for sorghum

The relationship for sorghum (Fig. 1) looks promising for all except low yielding crops, although surprisingly there is no clear indicator of different critical soil profile N contents (below which fertilizer responses are expected) for crops with different yield potentials and presumably N demands – although there are suggestions that lower yielding crops are less N limited when soil profile N at planting is <70-80 kg/ha in the top 120cm. The quantum of sorghum grain yield response to applied N (Fig. 2) increased as profile N reserves at sowing fell, with the rate of increase greater for sites and seasons where crop yield potential was high. These slopes are an indicator of the likely economic benefit of applied N.

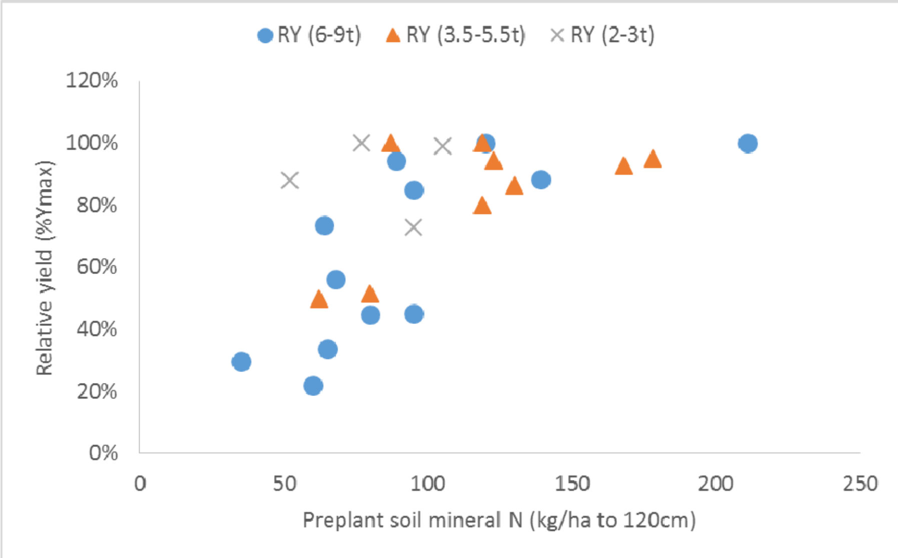

Figure 1. Relationship between relative sorghum grain yield (Y0/Ymax) and profile mineral N (sum of NH_4-N and NO_3-N) determined in soil tests taken prior to fertilizer application and crop sowing. Relationships are shown for soil profile depths of 120cm, with experiments with different seasonal yield potentials (2-3 t/ha, 3.5-5.5 t/ha and 6-9 t/ha) indicated by contrasting symbols.

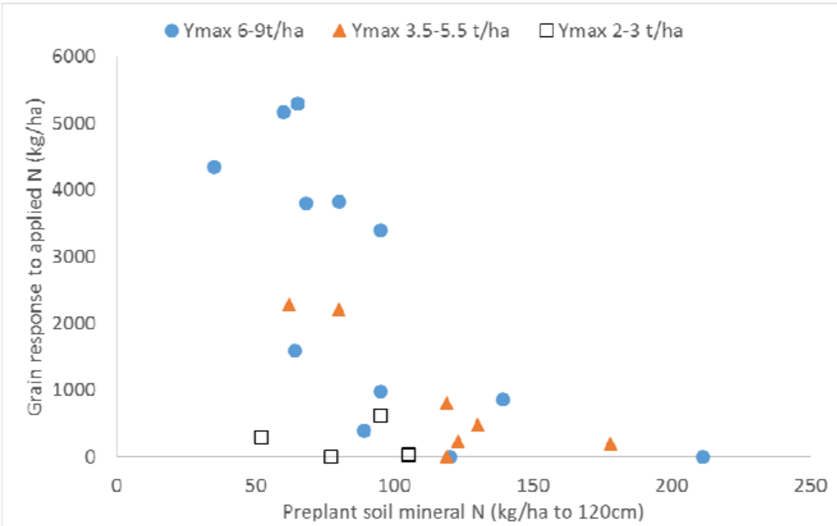

Figure 2. The quantum of sorghum grain yield response to applied N fertilizer (Ymax – Y0) plotted as a function of profile mineral N (120cm depth) at or prior to sowing. The steeper slope of the response surface in sites/seasons with a higher yield potential indicates greater returns on fertilizer N investment.

Phosphorus soil tests

The values listed below for P tests are what we currently use to determine if sites are likely to respond to P (starter P or deep bands), and it is a combination of the two distinct soil P test measurements that give the best indication of likely crop response. Colwell-P is measuring the labile, easily plant available P pool, whilst BSES-P measures not only this pool but also a pool that only releases P very slowly. The key difference is that this slow release pool will not release enough P fast enough to meet the demands of a rapidly growing crop, and so without some rapidly available Colwell P, addition of soluble P fertilizer is required.

Table 1. Generalised critical P values used to determine likely response or drivers of P availability in northern Vertosols

	Surface (0-10cm)		Subsoil (10-30cm)	
Colwell P	<25 mg/kg	Likely to get a response to starter P	<10 mg/kg	Likely to get a response to deep P placements
	>60 mg/kg	Ensure good groundcover to limit erosion risk!	>100 mg/kg	Unlikely to see P deficiency in your lifetime
BSES P	<25 mg/kg	Limited evidence of residual fertiliser accumulation	<30 mg/kg	Limited reserves of slowly available P. Consider replacement of removed P once every 5 years.
	>100 mg/kg	High residual fertiliser load	>100 mg/kg	Potential to slowly replace Colwell P reserves

There are species variations in the critical Colwell values according to species planted. For example maize and wheat require between 25-30 mg Colwell P/kg in the 0-10cm layer, while peanuts require only 12-15 mg/kg, with limited responses above that value. Although we have placed 'critical values' in the surface BSES tests in Table 1, we pay very little attention to these values. We are actually content with Colwell and PBI tests in 0-10 and 10-30, and BSES in the 10-30 only, at least once. Because BSES-P releases only slowly, movement in that value takes years, so does not need to be monitored annually.

Because P is an element that roots have to grow towards to maintain uptake, anything that limits the active extension and proliferation of roots will necessarily limit the accessibility of the P that is, at least in a soil test, considered available. Hence, soil conditions that inhibit root growth (sodicity, pH, salinity, nematode damage), necessarily increase the critical values because higher soil solution P concentrations are needed to match demand from a smaller root system. Under these circumstances we would encourage test strips be laid down to determine if remediation is economic. We remain uncertain of the responsiveness of crops to intermediate soil P values, but would expect variation based on the moisture regime the crop experiences each year.

The lower *critical* values in the subsoil for available P (and available K, below) reflect the larger soil volumes in a 10-30cm depth increment. By the time a plant root system requires nutrients from these depths, many of the yield limits such as grain number have been established in response to early P status (starter P and 0-10cm P status). What is needed by the plant then through to maturity is a long, regular arrival of nutrients from a more extensive and established root system. Plants will only rely on the nutrient status in these subsoil levels when times are hard near the surface. Surface moisture conditions through a season determine the dependence on subsoil nutrient resources, and consequently responses to deep placement. The excellent residual value we have seen from deep P applications in trials in a number of sites suggests that deep P placement followed by a season where topsoil supply dominates does not represent a waste of money. That deep P will be available to subsequent crops in the rotation.

Potassium soil tests

Potassium availability is a little more difficult to establish rules of thumbs for, but Table 2 below summarises our current thinking. Again, there are species differences in these values too. For the majority of species these values are about where we think responses are likely, however, we know that cotton requires higher K availability and critical values in cotton can be almost twice those reported in Table 2.

Table 2. Critical K values used to determine likely response or drivers of K availability in northern Vertosols

	Surface (0-10cm)		Subsoil (10-30 cm)	
CEC	ExK (cmol/kg)	High Mg (>30% CEC) or Na (>6% CEC)	ExK (cmol/kg)	High Mg (>30% CEC) or Na (>6% CEC)
<30 cmol/kg	0.2	0.4	0.1	0.2
30-60 cmol/kg	0.4	0.7	0.3	0.5
>60 cmol/kg	0.6	1.0	0.5	0.8

Considerably more work is required to improve the precision of these critical values, and to understand the mechanism behind the increase in those values where soil Na or Mg status is high. The two main mechanisms are direct competition at the root surface between these cations and K or changes in soil physical structure and aggregation that results in slower root extension and proliferation in the soil volume. It is highly likely that both are important in determining the availability of K to plants, but as yet we are only taking early steps in separating out these effects and understanding which plays a more significant role. Sorting out the importance of each of these mechanisms greatly affects how you manage them, as it will determine whether you attempt to broadcast K widely and enrich a much larger soil volume a little, or concentrate your K in multiple bands at various row spacing. The reason the critical value increases with CEC in Table 2 is because as the CEC of a soil increases, the buffer capacity of the soil for K increases along with it. In essence, the rate at which K is released from the soil to replace that taken up by a plant root is slower than the rate required by the plant root to maintain adequate K status, as the CEC increases. It is very similar to the way a high PBI in a soil increases the critical Colwell P value.

We are continuing to develop a method to estimate the slowly available reserves of K in each soil, with the tetra-phenyl borate extractable K (TBK) method still the most promising. A concerted push to develop testing methods for these slowly available pools is being undertaken by Chris Guppy (UNE) and Phil Moody (DSITI) in the next 3-4 years.

Through our current K field research, whole plant tissue K concentrations at maturity are emerging as a reasonable confirmation of soil K status.

Sulfur soil tests

Critical values for S responses in the surface are currently set at around 6 mg/kg of KCl-40 extractable S and in the subsoil, this would fall to around 4 mg/kg. However, we are currently recommending taking a deeper subsoil test for S, from 30-60cm depth. This is simply because S is far more mobile in the soil profile of heavier clay soils than either P or K, and hence, depending on rainfall, can move vertically in the soil column and be found at deeper depths. Responsiveness to S, where subsoil S is low, is also affected by soil moisture status. A dry topsoil, where organic S reserves accumulate, limits the mineralisation and release of S associated with that organic matter. Often a transient S deficiency can occur in prolonged dry periods, but is relieved with rainfall. At the very least, we are advocating monitoring S levels through the surface 60 cm.

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