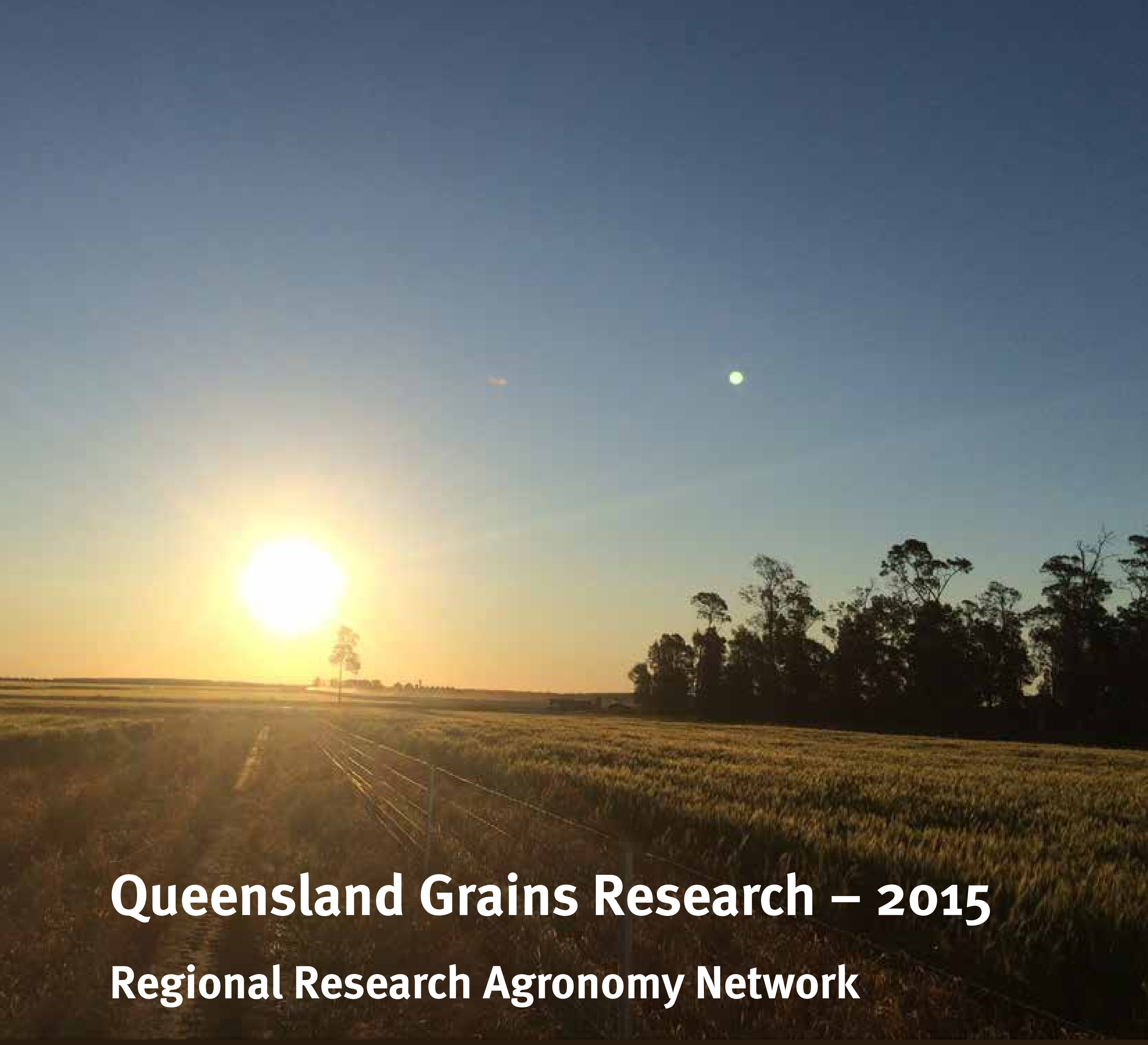

Queensland Grains Research – 2015

Regional Research Agronomy Network

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

Queensland Government

This publication has been compiled by Jayne Gentry and Tonia Grundy on behalf of the Regional Agronomy Team of Crop and Food Science, Department of Agriculture and Fisheries.

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Foreword

Queensland Department of Agriculture and Fisheries (DAF) delivers applied research and development (R&D) that promotes productive and profitable agriculture for grains cropping systems in partnership with the Grains Research and Development Corporation. The Queensland ‘Regional Research Agronomy Network’ (RRAN) is a new initiative based in the three major grain production nodes of Emerald (Central Highlands), Goondiwindi (Border Rivers/Maranoa) and Toowoomba (Darling Downs/Maranoa/South Burnett). The network of researchers and technicians conduct regional validation research trials across a range of grains cropping systems themes including pathology, agronomy, farming systems, weeds, physiology and crop nutrition.

This first trial book captures the essence of the R&D effort and its breadth the network have undertaken since their formation less than two years ago. The R&D is undertaken with the support of collaborating growers, local agronomists, seed companies and GRDC and aims to answer the questions of “how can this advance in grain production technology be applied for best results in this region”? The network is therefore an important part of the regional delivery of grains R&D, linking and adding value to the work and ideas of Australia’s leading grains researchers. Scientific rigour, regional focus, technical excellence and wide collaboration networks are the cornerstone behaviours of this team.

This trial book reports the individual trials the RRAN has undertaken across Queensland and are presented here to trigger discussion, exploration of the results, and highlight the next areas of exploration to answer further questions as we travel along the continuous improvement and increasing productivity journey in partnership.

We thank the team and the editors for their work in undertaking the trials, the data analysis and reporting the large array of papers in this first edition of the trial book.

Finally, we hope that these reports provide insight into how to gain higher productivity or profitability from your grains enterprise. We welcome any feedback or insights into the trials and results reported in this book and look forward to the RRAN providing on-going valuable insights into grains production in Queensland.

Garry Fullelove

General Manager, Crop and Food Science

On behalf of the

The Queensland Regional Research Agronomy Network

Department of Agriculture and Fisheries

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Research Facilities

The regional research trials reported here would not have been possible without the support of dedicated Technical Officers and Operational Officers at DAF's major research facilities across the grain region. Thanks to all those staff at the Hermitage Research Station (near Warwick), the Leslie Research Facility (Toowoomba), the Bjelke-Petersen Research Station at Kingaroy and staff based at the Emerald Agricultural College for their operation of heavy plant and research machinery.

Biometry support

The DAF biometry team has provided the statistical analysis of the data presented in this report.

Cereal agronomy research

Cereal grain production is the mainstay of broad acre dryland cropping in Queensland and has been the focus of agronomic research in the Department of Agriculture and Fisheries (DAF) for many years. In early 2015, the newly formed Regional Agronomy team joined the Variety Specific Agronomy Package (VSAP) initiative that the Department of Primary Industries, New South Wales (NSW DPI) has been leading and trials were extended into Queensland. The following trial reports cover this first year's research across Queensland.

The VSAP research aims to better understand the variety specific characteristics or phenology of new and established varieties. This will help growers know what to expect from a specific variety or maturity group under their own planting conditions and so make more informed management decisions.

In response, the team developed six sites across the Southern and Central Queensland wheat growing regions to evaluate the following questions:

- What effect will altering the time of sowing for 18 different wheat varieties of varying maturities have on phenology and yield? Do any observed differences remain consistent from region to region?
- Can observed differences be used to optimise planting times?
- What is the impact of varying planting rates in wheat?
- Do different varieties respond differently to varying populations?
- Is there a varietal difference in yield and protein response to nitrogen application?

A considerable amount of agronomic research on these topics (populations, nitrogen responses, variety differences) has been done in the past. However, as breeding programs continue to develop new varieties with specific attributes, this research ensures that the phenology characteristics of new varieties are addressed. So what once held true for one variety or maturity in one region may not hold true in other regions or varieties of assumed similar maturities. For example, in a time of sowing comparison between Emerald and Goondiwindi this year, the variety LongReach Spitfire⦶ planted from the same seed lot within the same week (12/05/2015 at Emerald, 18/05/2015 at Goondiwindi), took only 70 days to flowering at Emerald versus 112 days to flowering at Goondiwindi.

It is important to remember that the data presented in the following reports on the VSAP program in Queensland is based on only one year's data. So, while there were some very interesting trends at the various sites, we strongly suggest growers continue to refer to the 2016 National Variety Trial (NVT) planting guides and yield results for their variety recommendations and planting times before making any significant management changes.

⦶ denotes that this variety is protect by Plant Breeder's Rights (PBR) unauthorised commercial propagation or any sale of propagating material of this variety is an infringement under the Plant Breeder's Rights Act 1994

Wheat time of sowing trial – Emerald 2015

Wheat varieties and the effects of different planting dates - Emerald

Darren Aisthorpe, David Reid and James Hagan
Department of Agriculture and Fisheries

Research Question: *What effect will altering the time of sowing of wheat varieties from varying maturities have on phenology and yield in Central Queensland?*

Key findings

1. There was a significant yield difference between times of sowing
2. There was minimal difference in yield when compared to population
3. Maturity order of varieties, didn't vary significantly within sowing times, however time to maturity between sowing times can vary significantly

Background

The Variety Specific Agronomy Package (VSAP) program is a continuation of co-funded research between New South Wales Department of Primary Industries (NSW DPI) and Grains Research Development Corporation (GRDC) under the VSAP program since 2009. This work was contracted to the Department of Agriculture and Fisheries (DAF) Regional Research Agronomy Network (RRAN) to complete six trials per year across the Queensland grain belt for the first time in 2015.

Optimising planting time for a variety is a critical factor in achieving maximum yield potential. There are a range of long, medium and short season varieties available. Understanding how the varieties perform under a range of environmental conditions and planting times will allow growers to better optimise the balance between regional frost risk and yield loss. The trial in Emerald was designed to better understand, over a range of varieties, how time of sowing affects the phenology and potential yield within the Central Queensland (CQ) region.

The VSAP trials conducted at the Emerald Research station in 2015 included:

- Wheat variety x nitrogen
- Wheat variety x 3 times of sowing (TOS)
- Wheat variety x plant population

These trials were repeated in Goondiwindi and Warwick.

Treatments

Eighteen wheat varieties were sown across three sowing times each four weeks apart. These varieties were then monitored to measure emergence levels, flowering dates, yield and grain qualities post-harvest.

Varieties used at the 2015 Emerald trial site are listed below. The treatment list was specifically selected to represent a wide range of maturities, new and old varieties, with both prime hard and Australian hard varieties in the mix.

Quick

- LongReach Dart⌽
- Condo⌽
- Sunmate⌽
- LongReach Spitfire⌽
- Elmore CL Plus⌽
- Suntop⌽

Mid-season

- LongReach Crusader⌽
- Kennedy⌽
- LongReach Viking⌽
- Baxter⌽
- EGA Burke⌽
- Mitch⌽

Long-season

- LongReach Gauntlet⌽
- Sunguard⌽
- LongReach Lancer⌽
- EGA Gregory⌽
- Strzelecki⌽
- EGA Eaglehawk⌽

VSAP time of sowing (TOS) trial planting dates were selected to represent an early, traditional, and late planting time for the region or site where the trial was located. In this case the site was the Emerald Agricultural College with planting dates of 15 April, 12 May and 9 June.

Nitrogen (N) was applied pre-plant at 90 kg N/ha, to ensure N was not limiting, and 35 kg/ha of Granulock Z® was applied with the seed at planting. The Emerald site was planted on 50 cm row spacings using a tine parallelogram. Plot sizes were 12 m x 2 m, and each TOS had four replicates. The site was pre-irrigated twice to attempt to fill the profile with estimated planting moisture levels between 180–190 mm of moisture at each planting date.

After each planting event, post emergence (usually 2-3 weeks after planting), a light supplementary irrigation (20-30 mm applied) was applied to top up moisture levels to ensure each planting event had a full profile of moisture. This occurred after all three planting events, however after the final TOS received this initial irrigation, no additional water was added, in an attempt to replicate a CQ late winter planting.

Results

Most growers are now strongly conditioned to utilising varietal planting windows rather than considering actual varietal flowering dates. The key reason has always been about trying to mitigate frost risk, which has always been a significant threat throughout the Queensland wheat growing region.

However as varieties change, climate prediction models improve, and farming systems change, it is always interesting to perform checks against excepted knowledge and test what effect changing planting date may have on wheat varieties.

Days to Flowering

There was a wide spread of flowering dates within times of sowing and variation in days to flowering between times of sowing (Table 1). Interestingly the later the planting date, the narrower the difference in flowering dates between varieties became.

Mean flowering dates across TOS dates indicate a significant flowering date difference from TOS 1 to TOS 2, but no difference between TOS 2 and TOS 3 (Table 2).

Table 1. Interaction means for days to flowering for 18 varieties at 3 times of sowing - Emerald. Means within a time of sowing without a common letter are significantly different (P=0.05)

Variety	TOS 1 (15/04/15)		TOS 2 (12/05/15)		TOS 3 (09/06/15)	
	Days		Days		Days	
LongReach Dart⌽	60.5	a	68.0	a	69.5	a
Condo⌽	60.8	a	69.0	ab	70.2	a
Sunmate⌽	61.1	a	70.5	bc	71.4	a
LongReach Spitfire⌽	61.5	a	70.8	bc	74.4	b
Elmore CL⌽	66.9	b	72.5	c	77.3	c
Kennedy⌽	69.3	c	76.6	d	79.9	de
Suntop⌽	69.8	cd	75.5	d	77.8	c
LongReach Crusader⌽	69.9	cd	76.1	d	77.6	c
LongReach Viking⌽	71.5	de	78.5	e	81.1	ef
EGA Burke⌽	72.5	def	80.5	fg	82.2	f
Mitch⌽	73.4	fg	81.5	gh	81.1	ef
Baxter⌽	73.9	fg	79.6	ef	78.3	cd
Sunguard⌽	75.1	gh	83.1	h	81.4	ef
LongReach Gauntlet⌽	76.3	h	79.5	ef	81.0	ef
EGA Gregory⌽	78.4	i	87.2	i	86.8	h
LongReach Lancer⌽	79.8	i	85.9	i	84.2	g
Strzelecki⌽	91.5	j	97.4	j	89.1	i
EGA Eaglehawk⌽	129.6	k	113.9	k	96.4	j
l.s.d. w/i T	1.9					
l.s.d. b/w T	3.0					

Table 2. Mean flowering dates across time of sowing dates. Means without a common letter are significantly different (P=0.05). L.S.D – Least Significant Difference, S.E.D – Standard Error of the Difference

Time of sowing	Days to flowering	
TOS 1 (15/04/15)	74.6	a
TOS 2 (12/05/15)	80.3	b
TOS 3 (09/06/15)	80.0	b
s.e.d.	1.0	
l.s.d. (5%)	2.6	

Yield

On average, TOS 1 out-yielded TOS 2 by 750 kg/ha and TOS 3 by 1500 kg/ha, with approximately 95% of results falling between 285 and 1230 kg/ha benefit for TOS 1 over TOS 2 and between 1200 and 1900 kg/ha for TOS 1 over TOS 3 (Table 3).

There was a clear significant difference between each time of sowing mean yield, constantly decreasing from TOS 1 through to TOS 3 (Table 4).

At a wheat price of $250/t the potential benefit of taking advantage of early sowing opportunities with a full profile in 2015 could have ranged from $19 to $493/ha, depending on when next sowing opportunity occurred and variety chosen.

Table 3. Interaction means for yield for 18 varieties at 3 times of sowing - Emerald. Means within a time of sowing without a common letter are significantly different (P=0.05)

Variety (V)	TOS 1 (15/04/15) Kg/Ha		TOS 2 (12/05/15) Kg/Ha		TOS 3 (09/06/15) Kg/Ha	
Condo⌀	4191	abcd	3903	a	2991	a
Sunmate⌀	4155	bcd	3860	ab	2947	ab
Baxter⌀	4345	abc	3526	bcd	2918	abc
LongReach Spitfire⌀	4132	bcd	3816	abc	2817	abcd
Mitch⌀	4582	a	3352	d	2755	abcde
Elmore CL⌀	4371	abc	3540	bcd	2578	cdef
EGA Burke⌀	4409	ab	3378	d	2590	bcdef
LongReach Dart⌀	3974	d	3472	cd	2913	abc
Suntop⌀	4347	abc	3489	cd	2520	def
LongReach Crusader⌀	4383	abc	3325	d	2462	def
LongReach Gauntlet⌀	4394	ab	3273	d	2452	ef
LongReach Lancer⌀	4258	abcd	3520	bcd	2286	fg
Sunguard⌀	4189	bcd	3257	d	2606	bcdef
LongReach Viking⌀	4042	cd	3308	d	2316	fg
EGA Gregory⌀	4124	bcd	3218	d	2261	fg
Kennedy⌀	4082	bcd	3201	d	2273	fg
Strzelecki⌀	3585	e	2633	e	2322	fg
EGA Eaglehawk⌀	2097	f	2021	f	2087	g
l.s.d. w/i T l.s.d. b/w T	361.7 590.8					

Table 4. Mean Yields summary across time of sowing. Means within a time of sowing without a common letter are significantly different (P=0.05)

Time of sowing (T)	Yield (kg/ha)	Yield (% of TOS 1)	Yield (% of TOS 2)	
TOS 1 (15/04/15)	4092	100%	123%	a
TOS 2 (12/05/15)	3338	82%	100%	b
TOS 3 (09/06/15)	2561	63%	77%	c
s.e.d.	216			
l.s.d. (5%)	528			

Grain qualities

Grain qualities varied considerably, in line with the yield of the crop (Table 5). The highest yielding TOS 1 had generally lower proteins, but much lower screenings, test weight and 1000 grain weights. As you move across to TOS 2 and 3, with less in-crop water, higher proteins, higher screenings, lower test weights and 1000 grain weights were observed.

Table 5. Mean Summary table of grain quality attributes across the 3 times of sowing events. Means within a time of sowing without a common letter are significantly different (P=0.05)

Time of sowing	Grain Protein (%)		Screenings (%)		1000 Grain Weight (g)		Test weight (kg/hL)	
TOS 1 (15/04/15)	13.9	b	3.009	b	42.12	a	83.55	a
TOS 2 (12/05/15)	15.76	a	8.312	a	32.39	b	79.39	b
TOS 3 (09/06/15)	16.38	a	4.275	b	33.73	b	78.15	b
s.e.d.	0.6		0.85		1.15		0.83	
l.s.d. (5%)	1.48		2.09		2.81		2.02	

Implications for growers

With only one years' worth of data, definite conclusions about what to expect from specific varieties in a specific region cannot be drawn. In 2015 there was a significant decline in yield from one time of sowing to the next. It was also evident, despite some minor place changes, generally the quick varieties were the quickest and the long season varieties were the longest. The duration of time from planting to flowering for each variety, can and will change.

How significant the change will be is dependent on a range of factors, climate being the most significant of them. With a minimal vernalisation period, thermal time accumulation being quicker, and day length being longer during winter (closer to the equator) than southern regions, the phenology and physiology of wheat (and other crops) in this region do change, which makes revisits to accepted agronomic practices so interesting in this part of the world.

Finally, returning to the planting date versus flowering date discussion at the start of the results section. Figure 1 shows the yield and flowering dates of all the varieties for all three times of sowing.

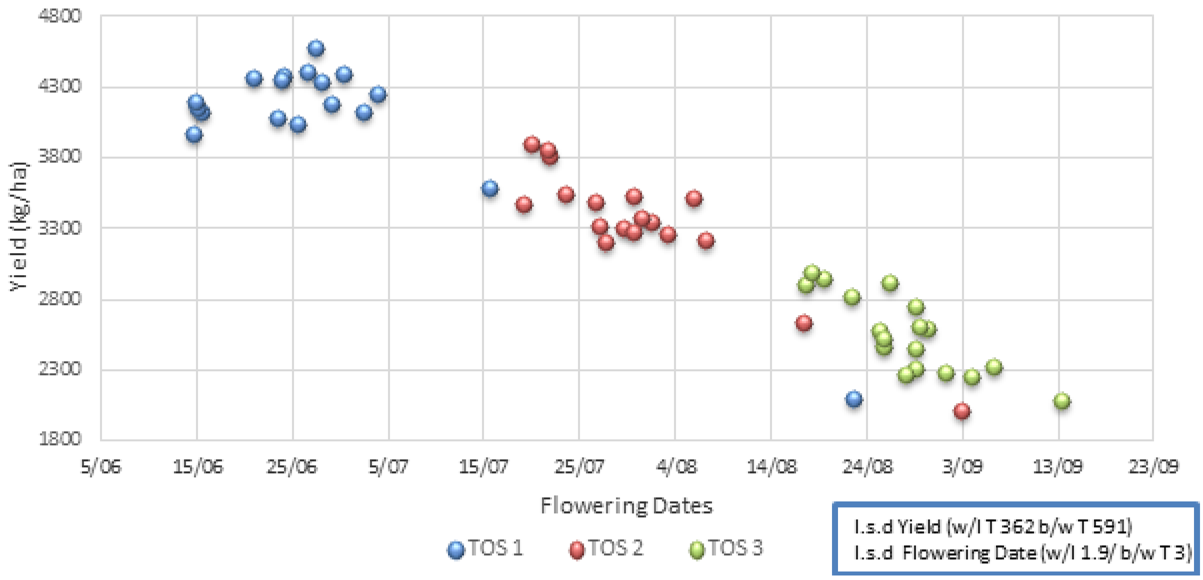


Figure 1. Yield difference between times of sowing, and critical flowering dates for each sowing date

When studying this graph consider;

1. individual locations' frost risk
2. when frosts usually occur
3. traditional planting time
4. which planting time would have been at greatest risk of frost damage at flowering based on these three sowing dates last year
5. how often those frosts would need to occur to outweigh the observed yield benefits of earlier seeding

CliMate (www.australianclimate.net.au/) and other web-based tools can be combined with local knowledge can be useful in building an understanding of heat and cold risks regionally and locality specific.

Acknowledgements

I would like to acknowledge all those who contributed seed for our trials to take place, in particular Ian & Gail Buss from Galion Grains, Regal Seeds Biloela, John Thelander from Seednet and the team from NSW DPI.

The project is funded by the Grains Research and Development Corporation, the New South Wales Department of Primary Industries and the Department of Agriculture and Fisheries.

Trial details

Location:	Emerald
Crop:	Wheat
Soil type:	Self Mulching grey vertosol over 1.5 m deep and a water holding capacity of approx. 170–200 mm
In-crop rainfall:	30 mm in-crop, sprinkler irrigations to fill profile pre 1st TOS, then approx. 50mm of irrigation after each TOS event (post emergent)
Fertiliser:	90 kg N/ha applied pre-plant (March 2015) and 35 kg/ha of Granulock Z® at planting

Wheat time of sowing trial Emerald 2015

Wheat varieties and the effects of different planting dates – Goondiwindi

Andrew Erbacher, David Reid and James Hagan
Department of Agriculture and Fisheries

Research Question: *What effect will altering the time of sowing of wheat varieties from varying maturities have on phenology and yield in South West Queensland?*

Key findings

1. Planting late resulted in significant yield reductions for all varieties
2. In Goondiwindi, the probability of heat stress far exceeds frost risk for crops planted in the conventional planting window
3. Earlier planted wheat produced more grain per mm of water (i.e. a higher Water Use Efficiency)

Background

The wheat breeding companies and the National Variety Trial (NVT) initiative identify the optimum planting dates for wheat varieties to form each maturity group. The optimum planting date is important to maximise yields by balancing the risks of frost damage at flowering and heat stress during grain-fill. However, the best economic choice of varieties must also account for the necessary disease and other agronomic traits required for local farming systems.

The Goondiwindi site selected was under a centre pivot on an alluvial soil on the Weir River. This site allowed the opportunity for supplementary irrigation to ensure planting opportunities on the required date, which was not necessary this year (2015). The paddock was long fallowed out of cotton and had 100 mm of plant available water and 360 kg N/ha at the time of the first planting date. Predicta B tests revealed no pathogens that would impact on wheat yield.

Treatments

Eighteen (18) varieties were planted on three different time of sowings (TOS) at four week intervals:

- 27 April (TOS 1)
- 26 May (TOS 2)
- 8 July (TOS 3)

The varieties in order of increasing maturity from slow to quick (Queensland 2015 NVT wheat varieties guide) were: EGA EaglehawkⒹ, StrzelekiⒹ, LongReach LancerⒹ, EGA GregoryⒹ, SunvaleⒹ, LongReach GauntletⒹ, EGA BurkeⒹ, SunguardⒹ, MitchⒹ, Elmore CL PlusⒹ, LongReach VikingⒹ, BaxterⒹ, KennedyⒹ, SuntopⒹ, LongReach SpitfireⒹ, LongReach CrusaderⒹ, SunmateⒹ, LongReach DartⒹ.

Results

The trend was for 'days to flowering' to decrease as the varieties were planted later in the season (Table 1). This may be attributed to increasing temperatures and lengthening days. The exceptions to this trend were the quick maturing varieties LongReach DartⒹ and LongReach SpitfireⒹ. These varieties went right through to anthesis during the cooler conditions of the second sowing date, whereas the longer varieties ran into warmer conditions and flowered more rapidly than the first sowing.

The average grain yield reduced significantly between TOS 1 and TOS 2. Yields reduced further from TOS 2 to TOS 3, which was not significant overall, but was significant in eight of the eighteen varieties in this trial.

The yield data (Figure 1) suggests that in this trial, varieties that were able to flower at or before the first week of September were able to achieve close to their yield potential. The varieties flowering after the 20 September suffered a yield penalty as a result of heat stress of consecutive days above 30°C during anthesis and early grain-fill. Varieties flowering in the period from 8 to 16 September (104 to 112 days after TOS 2) appeared to show differing tolerance to heat stress. Within this period the trend was for decreasing yield in the later flowering varieties, however there was up to 30% difference in yields between varieties that shared the same date of 50% anthesis.

Table 1. Days after planting to 50% anthesis and final grain yield (standardised for moisture) for three planting dates. Letters indicate significant difference of yield between varieties within a time of sowing. Values that share common letters are not different. For the average the letters indicate differences between the TOS (P=0.05)

Variety	TOS 1 (27th April 2015)			TOS 2 (26th May 2015)			TOS 3 (8th July 2015)		
	Days to 50% Anthesis	Grain Yield (t/ha)		Days to 50% Anthesis	Grain Yield (t/ha)		Days to 50% Anthesis	Grain Yield (t/ha)	
Average	114 a	4.05	a	109 b	3.07	b	91 c	2.00	b
LongReach Dart$^{\phi}$	96	4.13	abcde	99	3.87	a	83	2.67	ab
LongReach Spitfire$^{\phi}$	102	4.18	abcd	105	3.91	a	91	2.41	abc
Sunmate$^{\phi}$	107	4.33	abc	106	3.86	a	87	2.76	a
Elmore CL Plus$^{\phi}$	108	4.56	ab	106	3.34	ab	90	1.67	cd
LongReach Crusader$^{\phi}$	109	4.06	abcde	105	3.43	ab	86	2.07	abcd
Baxter $^{\phi}$	110	4.13	abcde	108	3.41	ab	89	2.24	abcd
Kennedy$^{\phi}$	113	3.89	cde	108	3.05	bcd	95	1.74	cd
Suntop$^{\phi}$	114	4.12	abcde	107	3.42	ab	90	2.58	ab
LongReach Viking$^{\phi}$	114	4.38	abc	110	2.61	cde	91	2.19	abcd
Sunguard$^{\phi}$	115	4.03	abcde	109	2.95	bcd	91	1.68	cd
LongReach Gauntlet$^{\phi}$	116	4.32	abc	108	3.15	bc	93	1.65	cd
Sunvale$^{\phi}$	117	3.94	bcde	111	3.03	bcd	93	1.92	bcd
EGA Burke$^{\phi}$	117	4.58	a	110	2.51	de	92	1.64	cd
Mitch$^{\phi}$	119	4.33	abc	110	3.50	ab	89	2.57	ab
LongReach Lancer$^{\phi}$	120	4.37	abc	111	2.67	cde	95	1.53	d
EGA Gregory$^{\phi}$	121	3.54	e	112	2.52	cde	92	2.12	abcd
Strzelecki$^{\phi}$	124	3.63	de	116	2.23	ef	92	1.96	bcd
EGA Eaglehawk$^{\phi}$	139	2.48	f	121	1.72	f	96	1.65	cd

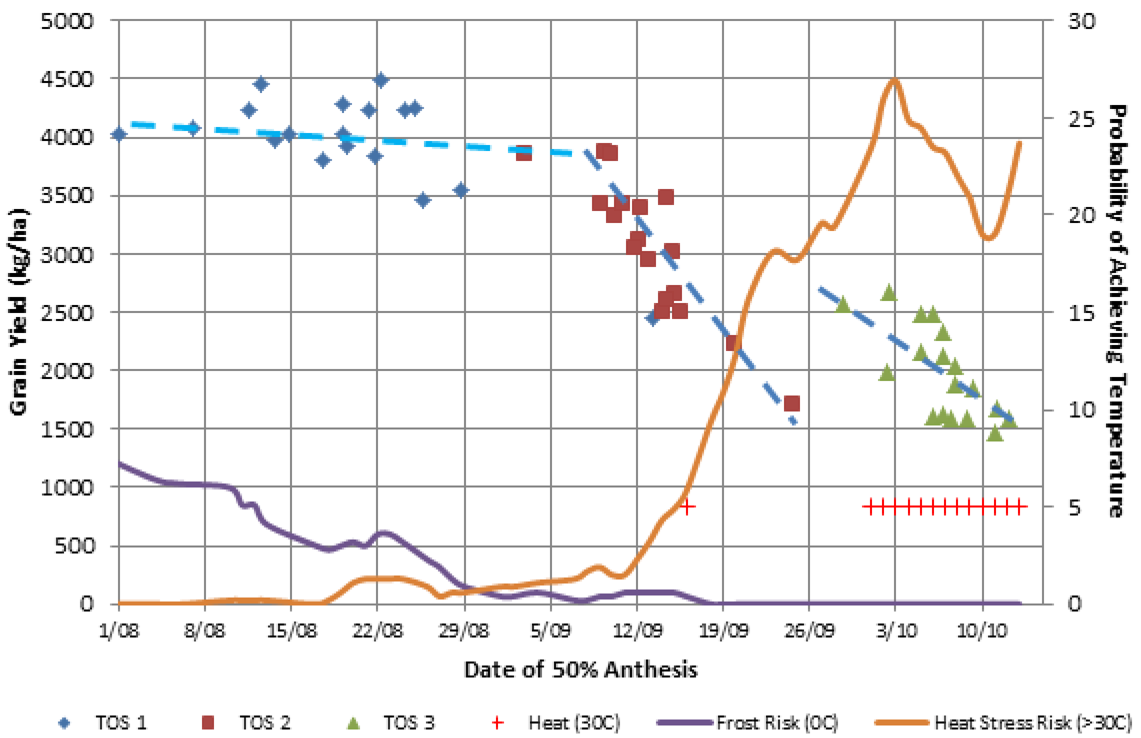


Figure 1. Grain yields of wheat for the date at which 50% anthesis occurred. The lines indicate the probability of Goondiwindi screen temperatures <0C and >30C (www.australianclimate.net.au). (+ indicates the days when Goondiwindi was >30C in 2015).

The highest yielding varieties in the presence of heat stress in this trial were LongReach Spitfire⊕, LongReach Dart⊕, Sunmate⊕ and Mitch⊕.

The Water Use Efficiency (WUE) data shows that later planting dates had access to less water, but also used that water less efficiently (Table 2). If the three planting dates had achieved the same WUE (13.6 mm/kg), estimated yields would have been 4.1 t/ha, 3.6 t/ha & 3.5 t/ha for TOS 1, 2 & 3 respectively. This represents a yield gap of 0.5 t/ha and 1.5 t/ha for the two later planting dates. A large part of this yield gap is that the later planted wheat used more water through transpiration as a coping mechanism to heat stress during flowering and grain fill.

Table 2. Average grain yield and water use across the three planting dates. Means without a common letter are significantly different (P=0.05)

Time of Sowing (TOS)	TOS 1	TOS 2	TOS 3
Grain Yield (t/ha)	4.05a	3.07 b	2.0 b
Fallow Water (mm)	102	102	131
In-crop Rainfall (mm)	195	165	126
Total PAW (mm)	297	267	257
WUE (kg/mm)	13.6	11.5	7.8

There was no difference in costs between the different time of sowing treatments, so any increase in yield can be considered an addition to net profit. Each variety performed better at TOS1 than TOS2, with an average benefit of approximately $260/ha at a farm gate wheat price of $250/t (Table 3). In contrast TOS 3 received a yield penalty across all varieties, averaging $270/ha less than TOS2.

Implications for growers

While frost can have significant yield implications, heat stress appears much more likely to reduce yields. This effect is likely to be stronger the further north and west you go in Queensland. Yields are likely to be maximised by planting as early as possible within the planting window for any particular variety, avoiding periods of heat stress during flowering and grain-fill.

There does appear to be varietal differences in the ability to yield under heat stress. If logistics and planting opportunities dictate a later than preferred planting date, then varietal selection would help reduce this impact.

Various tools such as the we-based CliMate (www.australianclimate.net.au) can be very useful in understanding heat and cold risks for your location.

Acknowledgements

I would like to thank the co-operators for hosting this trial site. This project is funded by the Grains Research and Development Corporation, the New South Wales Department of Primary Industries and the Department of Agriculture and Fisheries.

Trial details

Location:	Goondiwindi, Queensland
Crop:	Wheat
Soil type:	Black vertosol
In-crop rainfall:	195 mm, 165 mm & 126 mm
Available nitrogen:	360 kg/ha
Colwell phosphorus (0-10 cm):	58 mg/kg

Table 3. Differences in performance vs time of sowing 2 ($/ha)

	TOS 1	TOS 2	TOS 3		TOS 1	TOS 2	TOS 3
LongReach Dart⊕	$125	$0	-$300	Sunguard⊕	$125	$0	-$300
LongReach Spitfire⊕	$125	$0	-$350	LongReach Gauntlet⊕	$125	$0	-$350
Sunmate⊕	$175	$0	-$250	Sunvale⊕	$175	$0	-$250
Elmore CL Plus⊕	$375	$0	-$375	EGA Burke⊕	$375	$0	-$375
LongReach Crusader⊕	$225	$0	-$325	Mitch⊕	$225	$0	-$325
Baxter⊕	$250	$0	-$250	LongReach Lancer⊕	$250	$0	-$250
Kennedy⊕	$300	$0	-$325	EGA Gregory⊕	$300	$0	-$325
LongReach Viking⊕	$475	$0	-$75	Strzelecki⊕	$475	$0	-$75
Suntop⊕	$300	$0	-$175	EGA Eaglehawk⊕	$300	$0	-$175

Wheat varieties and the effects of different planting dates – Warwick

Andrew Erbacher, David Reid and James Hagan
Department of Agriculture and Fisheries

Research Question: *What effect will altering the time of sowing of wheat varieties from varying maturities have on phenology and yield in southern Queensland?*

Key findings

1. Planting later resulted in reduced yield potential for six of the eighteen varieties
2. At Warwick, the risk of frost out ways the potential benefits of flowering early
3. Variety choice can reduce the risk of frost from early planting

Background

The wheat breeding companies and the National Variety Trials (NVT) program identify the optimum planting dates of wheat varieties. While the optimum planting date is important, the best economic choice can often be varieties with necessary disease and other agronomic traits required for your farming system.

This site was located on the Hermitage Research Station 8 km east of Warwick, located in the Southern Darling Downs. This area is typified by reliable rainfall, long cold winters and up to 20 frosts per year (CliMate - How often). For this site, CliMate r (www.australianclimate.net.au) recommends a flowering window of 1 September to 25 October if a 1-in-10 year risk of frost or heat stress is considered acceptable.

Treatments

Eighteen (18) varieties were planted on three different dates at four week intervals; time of sowing 1 (TOS 1) on 15 May, time of sowing 2 (TOS 2) on 12 June and time of sowing 3 (TOS 3) on 10 July.

The varieties in order of increasing maturity from slow to quick (Queensland 2015 NVT wheat varieties guide) were: EGA EaglehawkΦ, LongReach LancerΦ, EGA GregoryΦ, LongReach GauntletΦ, EGA BurkeΦ, EGA WylieΦ, SunguardΦ, MitchΦ, Elmore CL PlusΦ, LongReach VikingΦ, BaxterΦ, KennedyΦ, SuntopΦ, LongReach SpitfireΦ, LongReach CrusaderΦ, LivingstonΦ, SunmateΦ, LongReach DartΦ.

Results

The days to flowering generally decreased as the varieties were planted later in the season (Table 1). In seven varieties this shortened vegetative period resulted in lower yields, while there was no significant yield penalty for nine varieties, or for the site average of each planting. In contrast, three of the six earliest flowering varieties had higher yields from TOS 2 than the earlier TOS 1. In TOS 1, visual effects of frost were evident in the LongReach DartΦ plots during flowering. While not observed, it is assumed the other early flowering varieties (SunmateΦ, LivingstonΦ, LongReach SpitfireΦ, LongReach CrusaderΦ and BaxterΦ) also suffered decreased yield as a result of this frost event (highlighted in Table 1).

Only one of the 18 varieties had a yield benefit for planting before the traditional June plant (TOS 1 vs TOS 2). The traditional June plant improved yield in five varieties for an average benefit of 500 kg/ha compared to a later July plant (TOS 3).

The average yield increase from TOS 2 over TOS 3 by approximately 500 kg/ha, with a farm gate wheat price of $250/t, which equates to a $125/ha benefit from taking advantage of early sowing opportunities. Ultimately, the results highlight the large potential impact of variety and planting date interactions. The potential impacts for a grower deciding to plant early ranged from a benefit of 1.9 t/ha ($475/ha) to a penalty of -1.8 t/ha (-$450/ha) where frost impacted on the crop.

The decreased yield for later planting date was a result of the shortened days to flowering from increasing temperatures and lengthening of days. There was no evidence of heat stress in this trial as grain quality (test weight 78-80 kg/hL and screenings 2-5%) were consistent across all planting dates. Water use efficiency was also similar across the three planting dates (21 kg/mm for TOS1 and TOS 2 and 19 kg/mm

Table 1. Days after planting to 50% anthesis and final grain yield (at standard moisture) for three planting dates. Letters indicate significant difference of yield between time of sowing (TOS) within a variety. Values that share common letters are not different, and ns is no difference for TOS in that variety (P=0.05)

	Days to 50% Anthesis			Grain Yield (t/ha)					
Variety	TOS 1 (15 May)	TOS 2 (12 June)	TOS 3 (10 July)	TOS 1 (15 May)*		TOS 2 (12 June)		TOS 3 (10 July)	
Average	**119 a**	**111 b**	**94 c**	**5.5**	**ns**	**5.6**	**ns**	**5.0**	**ns**
LongReach Dart⏀	110	105	92	3.76	b	5.18	a	4.97	a
Sunmate⏀	111	109	92	5.64	ns	5.49	ns	5.40	ns
Livingston⏀	112	109	92	4.31	b	6.07	a	5.06	b
LongReach Spitfire⏀	114	103	92	4.79	b	5.95	a	5.20	ab
LongReach Crusader⏀	115	103	92	5.02	ns	5.38	ns	4.79	ns
Baxter⏀	116	104	92	5.00	ns	5.36	ns	4.45	ns
LongReach Gauntlet⏀	118	113	96	6.20	a	6.01	a	4.62	b
LongReach Viking⏀	119	113	95	6.38	a	5.43	b	5.82	ab
Elmore CL Plus⏀	119	113	95	5.42	ns	5.33	ns	5.04	ns
Sunguard⏀	119	112	95	6.10	a	5.64	a	4.92	b
Kennedy⏀	122	113	95	5.01	a	4.68	a	3.98	b
EGA Wylie⏀	123	111	95	6.10	a	5.51	ab	4.68	b
EGA Burke⏀	123	112	95	5.67	ns	4.96	ns	5.25	ns
Mitch⏀	123	114	94	6.16	ns	5.67	ns	5.34	ns
Suntop⏀	123	113	96	5.73	ns	5.79	ns	5.86	ns
EGA Gregory⏀	123	114	96	5.85	ns	6.55	ns	5.86	ns
LongReach Lancer⏀	124	117	99	6.13	a	5.82	a	4.21	b
EGA Eaglehawk⏀	132	121	100	5.66	ns	5.14	ns	5.19	ns

*highlighted varieties may have been affected by frost

for TOS 3). However, there was a significant reduction of test weight for TOS 3, which can be attributed to a 50 mm rainfall event in the late stages of development of TOS 3 and post-harvest of TOS 1 and TOS 2.

Implications for growers

Tools such as CliMate can be very useful in understanding cold and heat risks for your location. For this site, CliMate recommends a flowering window of 1 September to 25 October for a 1-in-10 year risk of frost or heat stress. In this season, the earlier varieties flowered within this window but still suffered yield decline as a result of frost (i.e. LongReach Dart⏀ flowered on 4 September; and Baxter⏀ on 10 September). The slowest flowering variety planted late also flowered within this window (EGA Eaglehawk⏀ on 17 October), but with no evidence of heat stress.

The flowering windows of varieties being planted and the risk of frost damage must be carefully considered. There is potential for earlier sowing times to provide yield advantages, however in this southern Darling Downs environment, the high risk of frost potentially outweighs the yield benefit of the earlier flowering dates. The right mix of varieties with different lengths to anthesis could assist in mitigating the risk of frost occurring during the flowering window. In this trial, the best outcome was achieved by waiting for the recommended planting window in the Queensland NVT Wheat Variety Guide. This allowed the selection of the variety that had the best agronomic traits (pest and disease resistance/tolerance) for the paddock.

Acknowledgements

This project is funded by the Grains Research and Development Corporation, the New South Wales Department of Primary Industries and the Department of Agriculture and Fisheries.

Trial details

Location:	Warwick, Queensland
Last crop:	Millet (cover crop)
2015 crop:	Wheat
Soil type:	Brown vertosol
In-crop rainfall:	151 mm, 145 mm & 174 mm
PAW:	109 mm, 117 mm & 88 mm
Nitrogen:	285 kg N/ha
Colwell P:	34 mg/kg

Wheat varietal response to nitrogen fertiliser - Emerald

Darren Aisthorpe and David Reid
Department of Agriculture and Fisheries

Research Question: *Is there a varietal difference in yield and protein response to nitrogen application in Central Queensland?*

Key findings

1. Even at high nitrogen conditions there was a significant protein response between varieties, but not across nitrogen treatments
2. There was no significant difference across varieties when comparing yield and protein of the split application to the 100% up front application of nitrogen

Background

The Variety Specific Agronomy Packages (VSAP) program is a continuation of co-funded research between New South Wales Department of Primary Industries (NSW DPI) and Grains Research Development Corporation (GRDC) since 2009. This work was contracted to the Department of Agriculture and Fisheries (DAF) Regional Research Agronomy Network (RRAN) to complete six trials per year across the Queensland grain belt for the first time in 2015.

The driver for this trial has come from ongoing work which has been conducted by the NSW DPI VSAP program over the past few years in northern NSW. Nitrogen (N) is the nutrient needed in greatest quantity by wheat for growth and to maximise yield. Protein levels of less than 10.5% in a prime hard variety usually indicate that insufficient N levels have not only limited grain protein concentrations but also yield.

Over a number of trials it has been noticed that not all varieties respond the same way to increased available N. Some varieties tend to increase yield first at the expense of protein, others would work the other way round, tending to increase protein levels at the expense of yield. The aim of these trials is to better understand these varietal interactions, and to see if these interactions are consistent under Central Queensland (CQ) conditions.

The VSAP trials conducted at the Emerald Research station in 2015 included:

- Wheat variety x nitrogen
- Wheat variety x 3 times of sowing (TOS)
- Wheat variety x plant population

It is interesting to not only draw comparisons from within the one trial but between all three trials where appropriate.

Treatments

Five nitrogen rates

1. Nil
2. 75% of yield potential
3. 100% of yield potential
4. 150% of yield potential
5. Spilt application (75% at planting & 25% spread on at late tillering)

Five varieties

1. LongReach Spitfire⌽
2. Suntop⌽
3. Kennedy⌽
4. LongReach Lancer⌽
5. EGA Gregory⌽

Table 1. Calculated nitrogen treatments applied

Treatment	Yield potential (t/ha)	Calculated total N required (kg/ha)	N available at planting (kg/ha)	N applied at planting (kg/ha)	N applied late tillering (kg/ha)
Nil	2.6	82	82	0	0
75% YP	2.9	90	82	8	0
100% YP	3.8	120	82	38	0
150% YP	5.7	180	82	98	0
Split (100% YP)	3.8	120	82	8	30

Nitrogen application rates were calculated using yield potential (YP) estimates based on available water at planting (Table 1). The trial was planted on 11/12 May 2015 on 50 cm row spacings, and the required urea rates to achieve the calculated yield targets were applied via disc openers running in between the rows. This trial was planted at the same time as the second TOS trial; hence conclusions can be drawn across both trials. Average plant establishment was 50 plants/m².

Results

Early in the season the crop visually set itself up for high yield potential. It had a large biomass and tall plants, particularly when compared to the adjoining time of sowing trial. However, high starting N levels in the soil and a hot dry finish to the crop resulted in minimal significant differences across the trial (Table 2). Screenings and test weights were also affected across the treatments (Table 2), where all screening levels were above the delivery standard of 5% except for LongReach SpitfireΦ.

There were no significant differences across the average yields for the N treatments; however there were some differences between varieties, with LongReach SpitfireΦ highest yielding, followed by SuntopΦ and LongReach LancerΦ. Equally there were no significant differences between protein levels across N treatments, however there were clear varietal differences with LongReach LancerΦ achieving the highest average protein and SuntopΦ the lowest. Interestingly the highest yielding variety in this trial, LongReach SpitfireΦ, also had higher protein than SuntopΦ.

With the limited difference in yield between applied rates of 0 and 98 kg N/ha at this site, it is difficult to justify additional N applications for this water limiting season, with the upper rates potentially costing growers more than $50/ha (Table 3).

Table 2. Interaction means for the nitrogen rate x variety trial - Emerald. Means within a column without a common letter are significantly different (P=0.05) L.S.D – Least Significant Difference, S.E.D – Standard Error of the Difference

	Days to flowering		Yield (kg/ha)		Grain protein (%)		Test weight (kg/hl)		Screenings (%)		1000 seed weight (g)	
N Rates (R)	n.s.		n.s.		P=0.051		n.s.		n.s.		n.s.	
Nil	78.8		3368		15.6		80.36		7.7		33.9	
75%	78.8		3432		15.7		80.89		7.1		33.8	
100%	77.9		3531		15.9		80.71		7.3		33.2	
150%	79.1		3459		16.4		80.13		8.2		33.3	
Split	78.5		3405		16.3		79.98		8.3		33.3	
s.e.d.	0.53		138.2		0.34		0.48		0.66		0.85	
l.s.d. (5%)	-		-		0.72				-		-	
Variety (V)	***		***		***		***		***		***	
LongReach SpitfireΦ	69.69	e	3970	a	15.34	d	82.72	a	4.392	d	39.42	a
EGA GregoryΦ	86.25	a	3163	d	16.06	c	80.99	b	6.66	c	30.94	d
SuntopΦ	74.71	d	3565	b	14.65	e	79.67	c	11.597	a	34.28	b
LongReach LancerΦ	84.32	b	3328	c	16.84	a	81.01	b	6.063	c	30.69	d
KennedyΦ	77.39	c	3165	d	16.38	b	77.92	d	9.117	b	32.14	c
s.e.d.	0.41		50.5		0.1		0.19		0.31		0.51	
l.s.d. (5%)	0.82		101.1		0.21		0.38		0.62		1.02	
R x V	n.s.		n.s.		*		*		n.s.		n.s.	
l.s.d. w/i T	-		-		0.5		0.94		-		-	
l.s.d. b/w T	-		-		0.83		1.29		-		-	

Table 3. Economic results

	Treatment Cost ($/ha)	Yield Benefit (kg/ha)	Net Benefit ($/ha)
Nil	0	0	0
75% YP	6	64	10
100% YP	29	163	12
150% YP	75	91	-52
Split (100% YP)	32	37	-23

As discussed before this N trial was a part of a suite of VSAP trials conducted on the Emerald Research station. The TOS 2 was planted on the same day and in the same field as the N trial. By utilising data from this TOS trial, a comparison of yield x protein can highlight an interesting comparison. Total N available to the TOS trial was a total of 172 kg N/ha (82 kg/ha existing N plus 90 kg/ha applied pre-plant). Varietal order, based on protein was similar for each TOS, with LongReach Lancer⁽ᶦ⁾ generally the highest protein and Suntop⁽ᶦ⁾ the lowest protein (Figure 1).

Implications for growers

With only one years' worth of data, definite conclusions about what to expect from specific varieties in a specific region cannot be drawn. The high starting fertility of the trial site and the dry season resulted in no significant differences between N treatments with respect to yield or protein.

Average yield and protein differences between varieties did emerge between treatments. A broader data set collected over a few years will allow clearer recommendations as to varietal response to protein x yield relationship to be drawn.

Acknowledgements

I would like to acknowledge all those who contributed seed for our trials to take place, in particular Ian & Gail Buss from Galion Grains, Regal Seeds Biloela, John Thelander from Seednet and Rick Graham and the team from NSW DPI.

This project is funded by the Grains Research and Development Corporation, the New South Wales Department of Primary Industries and the Department of Agriculture and Fisheries.

Trial details

Location:	Emerald
Crop:	Wheat
Soil type:	Self mulching grey vertosol over 1.5 m deep and a water holding capacity of approx. 170 – 200mm
In-crop rainfall:	150 mm (delivered via irrigation due to lack of rainfall)
Fertiliser:	35 kg/ha of Granulock Z ® applied with the seed

Wheat variety x nitrogen trail, Emerald

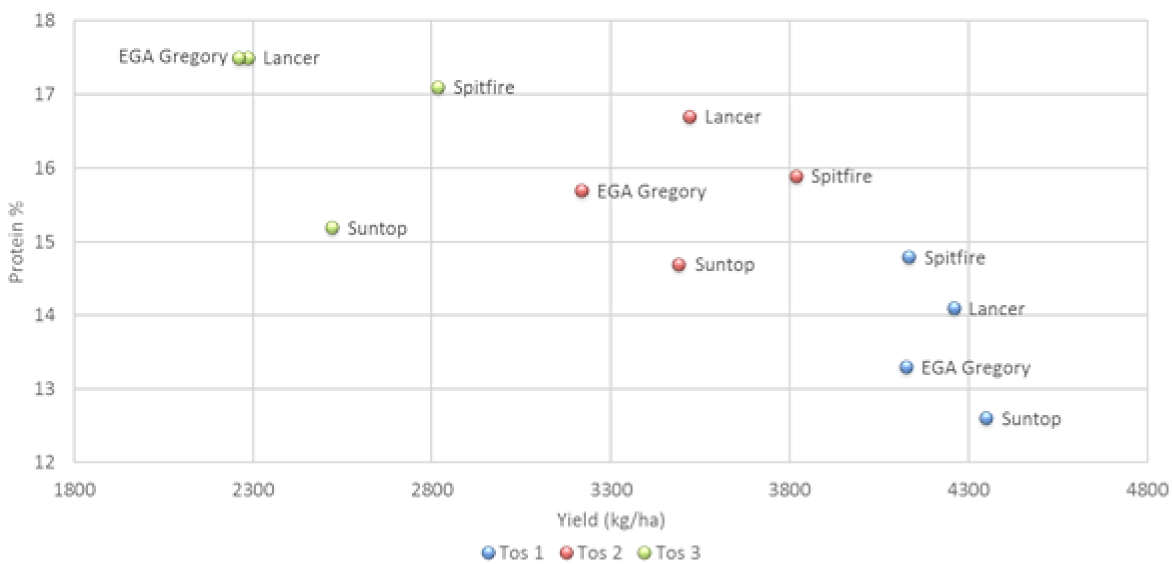


Figure 1. The influence of time of sowing added to variety x N comparison

Wheat varietal response to nitrogen fertiliser - Warwick

Andrew Erbacher and David Reid
Department of Agriculture and Fisheries

***Research Question:** Is there a varietal difference in yield and protein response to nitrogen application in Southern Queensland?*

Key findings

1. Increasing nitrogen rates improved grain protein in all varieties
2. Splitting nitrogen application between pre-plant and in-crop, provided an extra protein boost
3. There are varietal differences in protein achieved

Background

New wheat varieties are continually introduced and used commercially. Over time, there is a need to check the behaviour of these new varieties and their responses to the main agronomic practices that are used across the northern grains region.

Nitrogen (N) is a major cost for grain growers. Growers in all districts now use nitrogen fertilisers to grow good crops and to maximise their yields. There has also been a lot of research to help growers and their agronomists to refine their nitrogen strategies for wheat. However, much of this research was conducted many years ago on varieties that are no longer commonly used. Consequently, trials were established as part of the Variety Specific Agronomy Package (VSAP) to clarify the nitrogen responses of current varieties and so help growers get the best results in their local conditions.

The trial reported here was located on the Darling Downs at Hermitage Research Station 8 km East of Warwick. Wheat was planted on 25 cm rows with a target population of 100 plants/m^2.

Treatments

Soil tests for this paddock showed 138 kg N/ha to 90 cm prior to planting. Additional N fertiliser was then direct drilled into the soil immediately prior to planting in the form of urea, except the split application where half of the urea was applied pre-plant and the rest broadcast in-crop.

The yield potential of the site at planting was 5.5 t/ha; estimated by the APSIM model. Six nitrogen treatments including the split application were subsequently applied (Table 1):

1. Control (Nil)
2. 50% of yield potential
3. 75% of yield potential
4. 100% of yield potential
5. 150% of yield potential
6. 100% of yield potential as a split application

Five varieties were planted on 11 June:

1. LongReach Spitfire$^{\phi}$
2. EGA Gregory$^{\phi}$
3. Suntop$^{\phi}$
4. LongReach Lancer$^{\phi}$
5. LongReach Gauntlet$^{\phi}$

Table 1. Calculated nitrogen treatments applied (138 kg N/ha was available at the time of planting)

Rate	Budget Yield (t/ha)	Total Nitrogen required (kg/ha)	Nitrogen Applied Pre-plant (kg/ha)	N Applied Late tillering (kg/ha)
Nil	0	0	0	0
50%	2.75	104	0	0
75%	4.125	156	18	0
100%	5.5	208	70	0
150%	8.25	312	174	0
100% split	5.5	208	35	35

Results

The paddock nitrogen levels were higher than required for the 50% yield potential treatment, so these two treatments were combined for analysis. There was no significant 'variety x rate' interactions in this trial, therefore all differences measured were a direct result of either the variety or the nitrogen rate.

The higher rates of urea resulted in lower plant populations despite the pre-plant urea being applied in 50 cm bands that were off-set to the planting rows (Table 2). These lower populations impacted on yield (corrected to 12.5% moisture), but once the data was corrected for this effect, there was no significant difference in yield for nitrogen at this site. Nitrogen rates did have an impact on protein, with increasing rates of nitrogen improving the average protein across all varieties from 11.7% to 12.6%. For this site the late applied nitrogen in 100% split has been utilised by the plants to improve grain protein, with a 0.3% increase in protein above the equivalent amount of nitrogen applied up front.

Table 2. Effect of nitrogen rates averaged across all five varieties. Values within a column without a common letter are significantly different (P=0.05) L.S.D – Least Significant Difference, S.E.D – Standard Error of the Difference

N Rates (R)	Population (plants/m²)		Yield (kg/ha)	Grain protein (%)	
	***		n.s.	**	
Nil & 50% YP	97.1	a	5654	11.7	c
75% YP	94.0	ab	5794	12.0	bc
100% YP Split	91.2	ab	5742	12.8	a
100% YP	86.5	b	5721	12.5	ab
150% YP	77.1	c	5295	12.6	ab
s.e.d.	3.3		233	0.3	
l.s.d. (5%)	6.9		-	0.6	

Differences in seed germination and vigour also resulted in variable populations being established across the varieties (Table 3). The populations achieved were still commercially acceptable and did not reduce final yields, which were highest for the varieties with lowest populations. There was also evidence of varietal differences in the ability to produce protein, with LongReach Spitfire⦶ and LongReach Lancer⦶ achieving higher proteins.

Counting plant populations at Hermitage Research Station 2015

Table 3. Varietal differences in population established, yield and protein, averaged across all nitrogen rates. Values within a column without a common letter are significantly different (P=0.05) L.S.D – Least Significant Difference, S.E.D – Standard Error of the Difference

Variety	Population (plants/m²)		Yield at 12.5% (kg/ha)		Grain protein (%)	
1. LongReach Spitfire⦶	94.8	ab	5463	c	12.96	a
2. EGA Gregory⦶	90.9	bc	5663	bc	11.80	c
3. Suntop⦶	87.4	c	5939	a	11.21	d
4. LongReach Lancer⦶	78.8	d	5698	b	12.71	a
5. LongReach Gauntlet⦶	100.5	a	5455	c	12.39	b
s.e.d.	3.6		114		0.1	
l.s.d. (5%)	7.2		227		0.3	

Implications for growers

This trial demonstrated the impact high rates of nitrogen applied at the time of planting can have on plant establishment, even with good seed/fertiliser separation. As a result of this it would be desirable to increase seed rates slightly when planting and fertilising as a single pass operation.

Splitting nitrogen fertiliser between pre-plant and in crop applications has been demonstrated to give a protein boost, without impacting yield.

While there were no yield benefits measured in this trial, yield is only considered to be limited when protein is less than 10.5%.

Acknowledgements

This project is funded by the Grains Research and Development Corporation, the New South Wales Department of Primary Industries and the Department of Agriculture and Fisheries.

Trial details

Location:	Warwick, Queensland
Crop:	Wheat
Soil type:	Brown vertosol
In-crop rainfall:	145 mm
PAW:	185 mm
Nitrogen:	140 kg N/ha
Colwell P:	58 mg/kg

Wheat variety x population impact on yield - Emerald

Darren Aisthorpe, David Reid and James Hagan
Department of Agriculture and Fisheries

Research Question: *What is the impact of varying planting rates in wheat in Central Queensland? | Do different varieties respond differently to varying populations?*

Key findings

1. Yield effect on population stabilised at around 50 plants/m^2 established
2. Low populations still managed to achieve reasonable average yields across varieties
3. There may be some difference in how different maturities respond to population for a given planting time

Background

The Variety Specific Agronomy Packages (VSAP) program is a continuation of co-funded research between New South Wales Department of Primary Industries (NSW DPI) and Grains Research Development Corporation (GRDC) under the VSAP program since 2009. This work was contracted to the Department of Agriculture and Fisheries (DAF) Regional Research Agronomy Network (RRAN) to complete six trials per year across the Queensland grain belt for the first time this year.

Research conducted into optimum plant populations for wheat in the past has consistently indicated that a target rate of 100 plants/m^2 or 1 million plants per hectare is optimum for maximising yield. Actual observed populations from 20 to 80 plants/m^2 are frequent. A number of factors including; row spacing, depth of sowing, seed size, germination percent and vigour all play a significant role in dictating the population achieved.

With such a wide range of establishment rates experienced each season, how critical is this range on grower bottom lines? Where is the threshold between an acceptable establishment and a non-acceptable establishment and does this change based on the time of sowing?

The VSAP trials conducted at the Emerald Research station in 2015 included:

- Wheat variety x nitrogen
- Wheat variety x 3 times of sowing (TOS)
- Wheat variety x plant population

These trials were repeated in Goondiwindi and Warwick.

Treatments

Four target populations

1. 30 plants/m^2
2. 60 plants/m^2
3. 90 plants/m^2
4. 150 plants/m^2

Six varieties were tested

- LongReach Dart$^{\phi}$
- LongReach Spitfire$^{\phi}$
- Suntop$^{\phi}$
- Kennedy$^{\phi}$
- EGA Gregory$^{\phi}$
- LongReach Lancer$^{\phi}$

Planting date was 14 May 2015.

Nitrogen (N) was applied pre-plant (90 kg/ha) to ensure N was non-limiting and 35 kg/ha of Granulock Z® was applied with the seed at planting. The Emerald site was planted on 50 cm row spacings using a tine parallelogram. Plot sizes were 12 m x 2 m, and had four replicates. The site was pre-irrigated twice in an attempt to fill the profile and then a light irrigation was applied before the population trial was planted. It was estimated that planting moisture levels were between 180–190 mm.

Results

Establishment issues were significant but consistent. Seed germination and seed quality of some varieties may have contributed to the low establishment. Other problematic factors included:

- an irrigation system under extreme time pressure leading to inconsistent application
- new planting systems
- warm and very dry conditions

However, given the consistency of the germinations, we are still able to draw useful observations about the results.

Plant Populations

For the four plant population targets, only approximately 50% of that population was achieved (Table 1). A significant difference (l.s.d 5%) in emerged population was seen across all population ranges. The average plants established across varieties was variable, with LongReach Spitfire$^{\phi}$ slightly higher; however the very poor establishment of Kennedy$^{\phi}$ (and LongReach Lancer$^{\phi}$ to a lesser extent) may have been a result of seed quality issues, rather than a characteristic of the variety. Despite there being differences between varieties, no significant differences were seen when comparing varieties x populations.

Days to Flowering

Flowering dates of varieties were as expected, with LongReach Dart$^{\phi}$ the quickest and EGA Gregory$^{\phi}$ the slowest. This was consistent with what was observed within the Emerald VSAP time of sowing trials. There was also a significant difference between population rates, with the target 30 plants/m^2 group being significantly longer than the target 60 plants/m^2 and 90 plants/m^2 populations and the target 150 plants/m^2 population significantly faster again.

Yield

Despite the relatively low populations achieved across all target populations, the population to yield curve response was not as expected. As discussed above, accepted research indicates that as populations increase towards 100 plants/m^2 yield generally will follow. However yields achieved at the Emerald trial in this very dry year tended to flatten once established populations reached 40 plants/m^2.

Table 1. Interaction means for the population x variety trial - Emerald. Means within a column without a common letter are significantly different (P=0.05). L.S.D – Least Significant Difference, S.E.D – Standard Error of the Difference

	Population (plants/m^2)		Days to Flowering		Yield (kg/ha)		Test weight (kg/hL)		Screenings (%)		1000 seed weight (g)	
Target Pop. (plants/m^2)	***		***		***		***		***		***	
30	13.71	d	81.9	a	2599	c	77.95	b	11.29	a	33.83	a
60	29.1	c	79.57	b	3085	b	78.32	b	10.91	a	32.23	b
90	43.83	b	78.7	b	3194	ab	78.44	b	10.07	b	31.86	b
150	66.27	a	76.55	c	3378	a	79.33	a	9.49	b	31.56	b
s.e.d.	2.77		0.44		103		0.31		0.41		0.35	
l.s.d. (5%)	5.52		0.89		205.6		0.63		0.82		0.69	
Variety	***		***		***		***		***		***	
LongReach Dart$^{\phi}$	44.31	ab	68.59	e	3257	b	75.57	d	15.37	a	31.67	c
LongReach Spitfire$^{\phi}$	46.03	a	70.03	d	3551	a	78.87	b	10.31	c	34.85	a
Suntop$^{\phi}$	38.47	bc	78.07	c	2987	c	78.19	b	13.09	b	33.48	b
Kennedy$^{\phi}$	25.56	d	78.75	c	2805	c	76.85	c	10.83	c	31.04	c
LongReach Lancer$^{\phi}$	32.69	c	88.51	b	2915	c	80.99	a	6.27	d	31.36	c
EGA Gregory$^{\phi}$	42.31	ab	91.14	a	2870	c	80.57	a	6.77	d	31.81	
s.e.d.	3.39		0.54		126.1		0.38		0.5		0.42	
l.s.d. (5%)	6.76		1.09		251.8		0.77		1		0.85	
P x V	n.s.		***		n.s.		***		***		***	
l.s.d. (5%)	-		2.17		-		1.54		2		1.69	

Wheat yields appear to flatten once a critical mass of plants are established however the cost of increasing plant numbers is typically minimal, with the marginal cost of increasing seeding of around $3 per 10 kg once seed treatments and refill times are taken into account.

Assuming an expected field establishment rate of 60%, and a germination of 90% every increase in target population of 30 plants requires approximately 18 kg more seed, costing roughly $5/ha.

Table 2. Economics of seeding costs of various wheat populations

Seeding Cost ($/ha)	Target Population (plants/m²)	Observed Population (plants/m²)	Income ($/ha)
6	30	13.71	649.75
11	60	29.1	771.25
17	90	43.83	798.5
22	120	66.27	844.5

Whilst it may be possible to get acceptable returns from crops with low plant populations, the small cost of targeting higher populations with potentially greater returns, as well as benefits from crop competition for weed control, should provide growers with strong incentive to maintain robust seeding rates (Table 2).

This trend was somewhat variety dependent, with the quicker varieties maintaining yield growth as population increased e.g. LongReach Dart⁽ᴰ⁾ (Figure 1), whereas the yield of the mid and longer season varieties such as Suntop⁽ᴰ⁾ or EGA Gregory⁽ᴰ⁾ tending to plateau, once the population rose over 50 plants/m² (Figure 2).

When this VSAP population trial results are compared to the VSAP time of sowing population data (Figure 3), despite a wide range of plant establishment across all three of the time of sowing trials, population had little or no significant effect on the average yield for that sowing time in 2015.

Implications for growers

With only one years' worth of data, it is difficult to draw definite conclusions about specific varieties in a specific region. What was an interesting observation for 2015 however, was that despite some very low establishments, particularly in the target 30 plants/m² and 60 plants/m² groups, average yields of 2.6 and 3 tonne/ ha respectively were achieved across varieties.

These yields to have occurred in a commercial environment they would not be unacceptable nor would they justify a replant at a later date. The ability for the crop to compensate for lower populations is influenced by time of sowing, moisture availability, crop nutrition and varietal tillering ability, interestingly the responses in Central Queensland do not appear to correlate with the Southern Queensland experience in 2015.

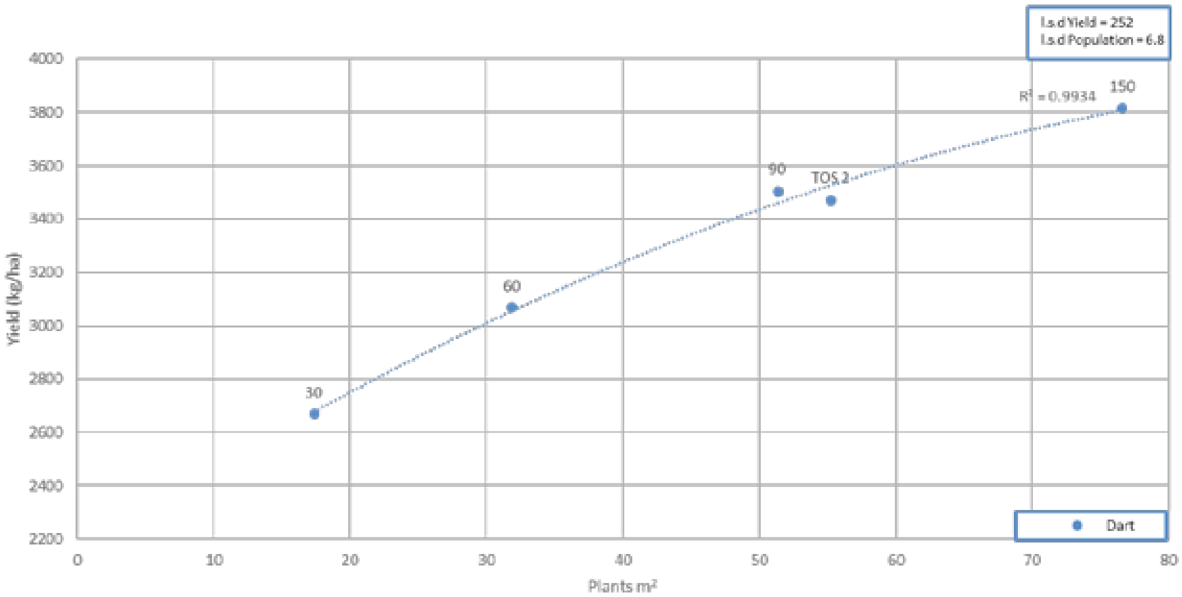


Figure 1. A 'traditional' yield response as seen in a quick variety like LongReach Dart⁽ᴰ⁾ at the 2015 trial site

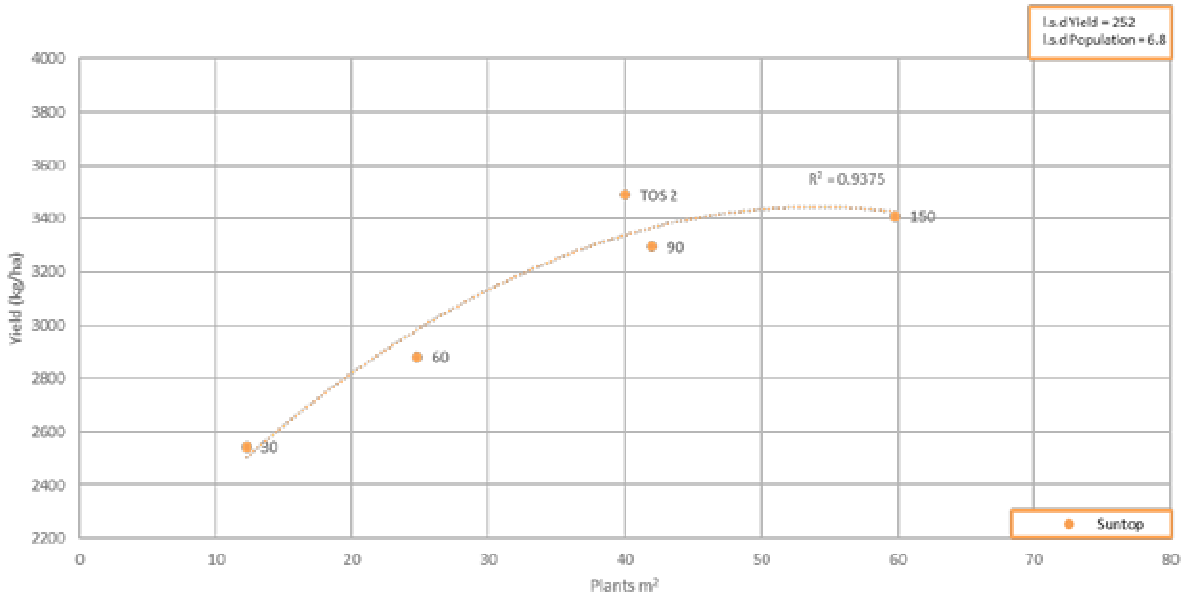


Figure 2. Medium maturity variety like Suntop⊕ showing signs of plateauing yield at only 40-50 plants/m² in the 2015 trial

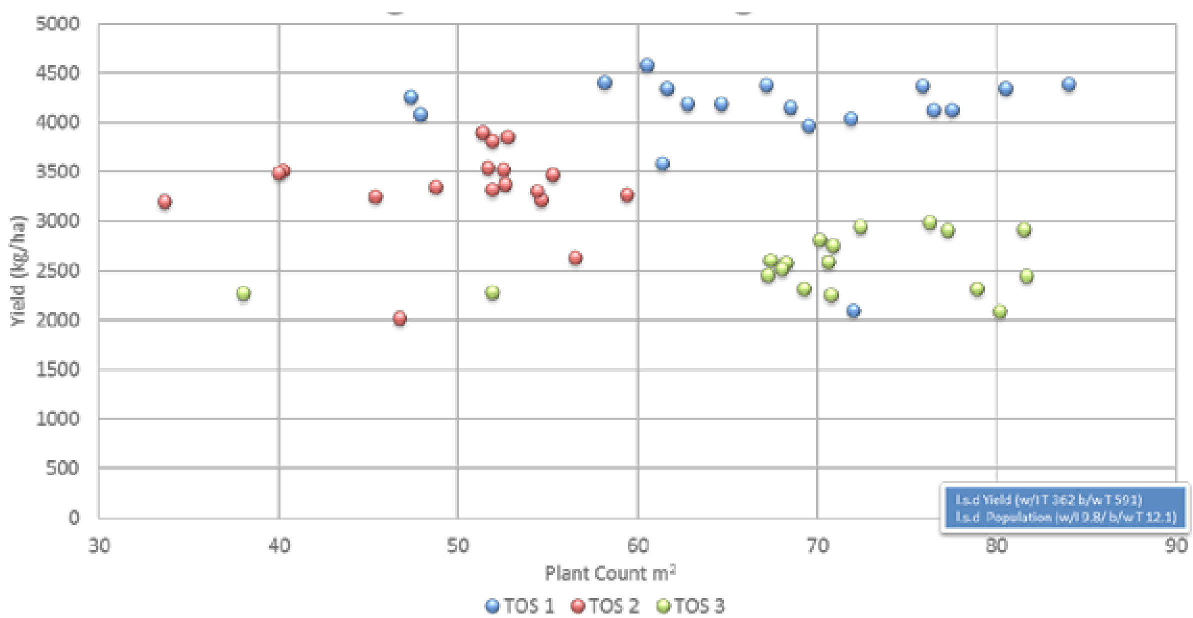


Figure 3. Average population x Yield comparison across times of sowing. TOS 1 (mid-April), TOS 2 (mid-May) & TOS 3 (mid-June)

Acknowledgements

I would like to acknowledge all those who contributed seed for our trials to take place, in particular Ian & Gail Buss from Galion Grains, Regal Seeds Biloela, John Thelander from Seednet and Rick Graham and the team from NSW DPI.

This trial is funded by the Grains Research and Development Corporation, the New South Wales Department of Primary Industries and the Department of Agriculture and Fisheries.

Trial details

Location:	Emerald
Crop:	Wheat
Soil type:	Self Mulching grey vertosol over 1.5 m deep and a water holding capacity of approx. 170–200 mm
In-crop rainfall:	30 mm in-crop, sprinkler irrigations to fill profile pre 1st TOS, then approx. 50 mm of irrigation after each TOS event (post emergent). (150 mm in total)
Fertiliser:	90 kg N/ha applied pre-plant (March 2015) and 35 kg/ha Granulock Z®

Wheat variety x population impact on yield - Goondiwindi

Andrew Erbacher and David Reid
Department of Agriculture and Fisheries

***Research Question:** What is the impact of varying planting rates in wheat on the Western Downs? | Do different varieties respond differently to varying populations?*

Key findings

1. Grain yields improved by increasing plant populations
2. Wheat yields increased to the maximum population achieved in the trial (62 plants/m^2)

Background

The argument of 'what planting rate I should be aiming for?' can be quite contentious. Current recommendations range from 30-150 plants/m^2. Consequently, grower practice also varies with populations from 20-100 plants/m^2 frequently observed.

A number of factors can dictate the final population achieved, including; row spacing, depth of sowing, seed size, germination percentage and vigour. Furthermore, the ability for the crop to compensate for lower populations is influenced by time of sowing, moisture availability and varietal tillering ability (e.g. LongReach Spitfire$^{\phi}$ has been shown to produce less tillers than Sunvale$^{\phi}$).

This site was located on the Western Downs, 12 km north of Goondiwindi, on Box soil adjacent to a melon hole Brigalow soil, which was highly sodic at depth (<30 cm). The wheat at this site was planted on 25 cm rows with a yield potential of 4.5 t/ha estimated by APSIM.

Treatments

Four target populations were planted on 28 May 2015.

1. 30 plants/m^2
2. 60 plants/m^2
3. 90 plants/m^2
4. 150 plants/m^2

Six varieties were tested

1. LongReach Dart$^{\phi}$
2. LongReach Gauntlet$^{\phi}$
3. EGA Gregory$^{\phi}$
4. LongReach Lancer$^{\phi}$
5. LongReach Spitfire$^{\phi}$
6. Suntop$^{\phi}$

Results

Poor plant establishment meant the trial failed to achieve the target populations (Table 1), however a spread of populations was achieved up to a maximum of 50 plants/m^2. Varietal differences were seen across these established plant populations. Regardless of the establishment issues this crop yielded on par with APSIM's median yield potential, with

Table 1. Actual populations established. Letters indicate significant differences within a variety (p=0.05). Values with like letters are not different.

Target Population (/m^2)	30		60		90		150	
Average	**15**	**a**	**26**	**b**	**34**	**c**	**50**	**d**
LongReach Dart$^{\phi}$	13	a	26	b	39	c	44	c
LongReach Gauntlet$^{\phi}$	15	a	32	b	42	c	62	d
EGA Gregory$^{\phi}$	14	a	27	b	33	b	54	c
LongReach Lancer$^{\phi}$	9	a	15	ab	23	bc	30	c
LongReach Spitfire$^{\phi}$	15	a	31	b	36	b	54	c
Suntop$^{\phi}$	24	a	24	a	29	a	46	b

an average maximum yield across all varieties of 3.3 t/ha and the best treatment yielding 3.9 t/ha.

There was no significant relationship between population and variety for grain yield; therefore changing population had a similar effect on all varieties to final grain yield. Average grain yields increased for increasing populations up to the maximum population achieved at this site (Figure 1).

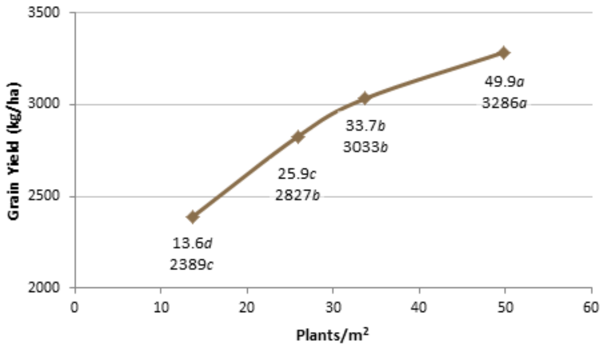


Figure 1. The relationship between grain yield and wheat population. Data labels show average achieved population and grain yield. Letters indicate significant difference (p=0.05) – values that don't share letters are significantly different

There were yield differences measured between the varieties. The main one being EGA Gregory$^{\phi}$ yielding poorly. There was a visual presence of crown rot in this trial, which EGA Gregory$^{\phi}$ is much less tolerant to than the other varieties. This is supported by the increased screenings measured in the EGA Gregory$^{\phi}$ (6-20% compared to 2-5% for the other varieties).

With EGA Gregory$^{\phi}$ removed due to the disease impact at the site, the average yield advantage from established plant population of 50 plants/m^2 compared to 15 plants/m^2 was approximately 1050 kg/ha. With a farm gate wheat price of $250/t, this amounts to $260/ha in additional income (Table 2).

Table 2. Benefit of targeting wheat populations greater than 30 plants/m^2 ($/ha)(avg. actual 15/$m^2$)

Average actual population	15/m^2	26-34/m^2	48/m^2
LongReach Dart$^{\phi}$	$0	$51	$203
LongReach Gauntlet$^{\phi}$	$0	$236	$344
LongReach Lancer$^{\phi}$	$0	$198	$287
LongReach Spitfire$^{\phi}$	$0	$172	$285
Suntop$^{\phi}$	$0	$62	$187
Average	**$0**	**$144**	**$261**

Implications for growers

Due to the lower than expected establishment rates at this site, we were not able to recommend an optimum planting rate. However, the results support the Department of Agriculture and Fisheries (DAF) claim that significant yield reductions may occur when established populations fall below 50 plants/m^2. It was also evident in this trial that the yields of all varieties responded similarly to varying populations in the absence of disease.

Acknowledgements

I would like to thank the co-operator for hosting this trial.

This trial was conducted as part of the Grains Research and Development Corporation, New South Wales Department of Primary Industries and Queensland Department of Agriculture and Fisheries funded Variety Specific Agronomy Package Project.

Trial details

Location:	Goondiwindi, Queensland
Previous Crop:	Wheat 2014
2015 Crop:	Wheat
Soil type:	Brigalow/Box Flat
In-crop rainfall:	170 mm
PAW:	100 mm
Nitrogen:	120 kg N/ha + 30 kg N/ha as urea

Harvesting Goondiwindi wheat population trial 2015

Wheat variety x population impact on yield - Warwick

Andrew Erbacher and David Reid
Department of Agriculture and Fisheries

Research Question: *What is the impact of varying planting rates in wheat on the Southern Downs? | Do different varieties respond differently to varying populations?*

Key findings

1. Maximum yield was achieved at 90 plants/m^2
2. Established percentage of plants reduced under high populations

Background

The argument of "what planting rate should I be aiming for" can be quite contentious, with current recommendations ranging from 30 to 150 plants/m^2. Consequently grower practice is equally variable with populations from 20 to 100 plants/m^2 frequently observed. A number of factors including row spacing, depth of sowing, seed size, germination percentage and vigour all play a significant role in dictating the population achieved. The ability for the crop to compensate for lower populations is influenced by time of sowing, moisture availability and varietal tillering ability (e.g. LongReach Spitfire$^{\phi}$ has been demonstrated to produce less tillers than Sunvale$^{\phi}$).

This site was located on the Darling Downs at Hermitage Research Station 8 km East of Warwick. The area is characterised by high frost risk for early sown crops, with mild springs giving extended grain fill periods. APSIM predicted a yield potential of 5.5 t/ha. The wheat at this site was planted on 25 cm rows.

Treatments

Four target populations were planted on 11 June 2015:

1. 30 plants/m^2
2. 60 plants/m^2
3. 90 plants/m^2
4. 150 plants/m^2

Six varieties were tested

1. LongReach Dart$^{\phi}$
2. LongReach Gauntlet$^{\phi}$
3. EGA Gregory$^{\phi}$
4. LongReach Lancer$^{\phi}$
5. LongReach Spitfire$^{\phi}$
6. Suntop$^{\phi}$

Results

Plant establishments were good at this site, with populations established close to the target for all varieties up to 90 plants/m^2. The highest density plots had evidence of plant competition reducing establishment, with only two varieties establishing 150 plants/m^2 for an average of 142.5 plants/m^2 (Table 1).

Table 1. Plant counts of established plants. Letters indicate significant difference (P=0.05)

Target Population (plants/m^2)	30	60	90	150
Average	**31.4***d*	**60.5***c*	**88.0***b*	**142.5***a*
LongReach Dart$^{\phi}$	36	62	90	127
LongReach Gauntlet$^{\phi}$	34	63	104	153
EGA Gregory$^{\phi}$	26	61	79	146
LongReach Lancer$^{\phi}$	25	54	76	123
LongReach Spitfire$^{\phi}$	36	65	90	150
Suntop$^{\phi}$	31	58	89	142

This was a well yielding crop with an average maximum yield across all varieties of 5.7 t/ha, with the best treatment yielding 6.2 t/ha. There was no significant relationship between population and variety for grain yield; therefore while yields were different between varieties, the effect of changing population on final grain yield was similar for all varieties. The overall trend was for a quadratic increase in grain yield as population approached 90 plants/m^2, with no significant difference to 150 plants/m^2 (Figure 1). There was also a significant trend for screenings to decrease as populations increased (2.5%a, 2.3%ab, 2.2%b and 2.0%c for 30 plants/m^2, 60 plants/m2, 90 plants/m^2 and 150 plants/m^2 respectively).

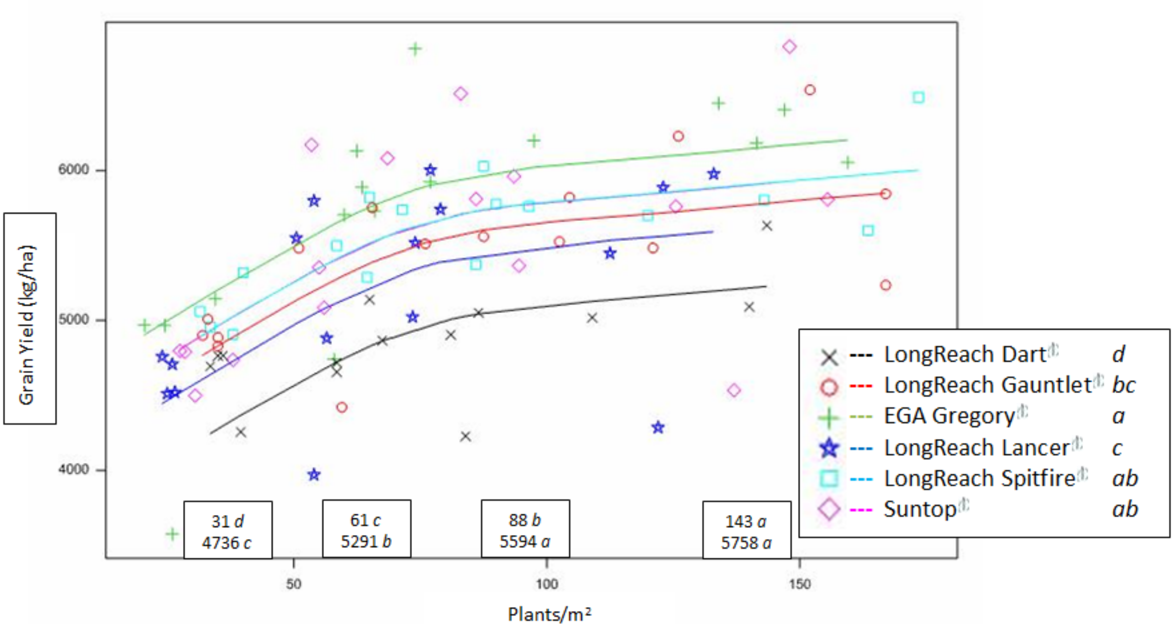


Figure 1. Grain yields for populations established of six wheat varieties. Numbers are average population and grain yields for all varieties. Letters indicate significant difference (p=0.05) nb. LongReach Spitfire⁽ᵖ⁾ and Suntop⁽ᵖ⁾ trend lines follow the same path

Implications for growers

This trial suggests the current Department of Agriculture and Fisheries recommendation of 100 plants/m² is optimal for most of the varieties tested. In this trial there was a yield penalty for established populations below 90 plants/m², whereas populations above this had similar yields with the added benefit of reduced screenings. Establishment percentage also reduced under high populations, so in similar high yielding situations it would be beneficial to increase planting rates slightly to allow for lower than expected establishment rates.

The effects of higher populations under high yielding situations will be investigated further in 2016 with a 200 plants/m² treatment being added at the Southern Darling Downs site.

Acknowledgements

This trial was conducted as part of the Grains Research and Development Corporation, New South Wales Department of Primary Industries and Queensland Department of Agriculture and Fisheries funded Variety Specific Agronomy Package Project.

Wheat variety x population trial - Warwick

Trial details

Location:	Warwick, Queensland
Crop:	Wheat
Soil type:	Brown vertosol
In-crop rainfall:	145 mm
PAW:	125 mm
Nitrogen:	140 kg N/ha
Colwell P:	58 mg/kg

Pulse agronomy research

Pulse crops are a vital component of modern conservation farming systems in Australia. They are for human consumption and stock-feed industries and can be very profitable in their own right. Being legumes, they can fix atmospheric nitrogen for their own growth and provide residual nitrogen for subsequent cereal grain and fodder crops. Pulse crops also provide significant rotation benefits by reducing pests (including nematodes, soil borne and foliar diseases and weeds), avoiding the need for some pesticides and enabling growers to rotate herbicide groups to control major weeds.

Despite significant rotational and economic benefits, adoption of pulse break-crops in Queensland farming systems has been relatively low, comprising 8% of the winter and 4% of the summer cropping areas. The area grown has been constrained by risks associated with unreliable yield, grain quality and inconsistent market price. Consequently, the Grains Research and Development Corporation (GRDC) established the National Pulse Agronomy Initiative to overcome these constraints and increase the area of pulses in modern farming systems. Key aims of the initiative were to validate and refine existing agronomic guidelines for growing pulses so growers can realise the potential yields of new varieties and double the area of pulses in their cropping systems. Farm profitability will be significantly increased if production can be reliably increased by as little as 10%.

Most of the following trials were conducted by this National Pulse Agronomy Initiative to identify the biophysical factors influencing pulse yields of these crops, and examined the effects of spatial configurations on canopy development, water uptake and use by plants to understand how the crop delivered its yield under those circumstances. Row spacing and plant population research was done initially to check and/or develop current recommendations for the new varieties that are becoming popular across Queensland. The main learnings from the project include:

- Narrower row spacings can produce higher yields in a variety of environmental conditions
- The percentage rise in yield from narrower row spacings increases in higher yielding situations
- Plant density has less influence on yield than row spacing and current planting recommendations should be continued
- Time of sowing has an effect on yield

Further work is proposed to better understand pulse crop partitioning. This research will use moisture probes to investigate rooting depth and water extraction and work in harvest index manipulation through the use of plant growth hormones and machinery to slow vegetative growth.

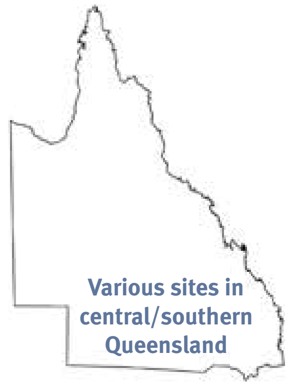
The remaining trial reports were produced as part of the Australian Government-funded Queensland Murray-Darling Basin Regional Economic Diversification Program (QMDB REDP) to improve the economic productivity from irrigated agriculture in the Queensland Murray-Darling Basin. The project is primarily focused on the irrigation sector within the Border Rivers and Balonne Catchments with the goal to: “Improve water productivity at the field and farm scale, resulting in increased economic activity and more profitable and resilient enterprises within the QMDB”.

Mungbeans

Chickpeas

Mungbean row spacing and plant population impact on yield

Rebecca Raymond[1], Kerry McKenzie[1], Douglas Sands[1] and Rao C. N. Rachaputi[2]
[1]Department of Agriculture and Fisheries
[2]QAAFI, University of Queensland



Research Question: *Does plant density or row spacing affect yield in mungbean?*

Key findings

1. Reducing row spacing to 50 cm and below will maximise mungbean yields
2. The improvement in yield is evident in differing environments and seasons
3. Plant population has less influence on yield

Background

Despite the potential environmental and economic benefits, the adoption of summer pulse crops in the Queensland grains region is around 4% of total cropping. 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.

One of the main aims of the Queensland Pulse Agronomy Initiative is to not only increase yields for summer (and winter) pulses, but to also improve the reliability of these yields. If the risk around yields in varied environments and seasons is reduced then pulses will not only be considered as a break crop in a cereal rotation or as an opportunistic cash crop, but also as a crop that can be considered a reliable and profitable part of the farming enterprise.

With mungbean yields averaging around 1 t/ha and a long term price of $750/t, an increase in yield of 10% could mean an extra return of $75/ha. Across a growing area of approximately 40,000 ha this increase could mean $3 million additional return to growers.

Treatments

This trial report includes a number of sites across Southern Queensland (SQ) and Central Queensland (CQ) where the same trial design was implemented to identify the effect of row spacing, variety and planting density on yield across two seasons 2013/14 and 2014/15. Each site had slight variations to align with regional priorities however there were consistent treatments included across all sites to allow for analysis.

The trials were designed to investigate if row spacing or planting density has an effect on yield. In order to do this a series of the following treatments were used: four cultivars (Jade-AU⊕, Crystal⊕, and breeding lines MO11047, MO11057) four planting densities (10, 20, 30 & 40 plants/m^2) and four row spacings (0.25, 0.50, 0.75 & 1.00 m) were used with three replicates of each.

Results

Row spacing effects

During 2014-15, row spacing and plant population trials were implemented at four sites in SQ (Miles, Warra, Dalby and Billa Billa) and two sites in CQ (Emerald and Baralaba). The treatments consisted of three row spacing treatments (0.25, 0.5, 1.00 m), three or four varieties (Jade-AU⊕, Crystal⊕, MO11047, MO11057), with a plant population of 30 plants/m^2. All trials were managed by the cooperating grower as part of their commercial crop to avoid interference from pests or diseases. The Miles trial is not presented in this report as data was compromised due to waterlogging. It was determined that the results observed were mainly due to the abiotic constraints (temperature and water). As the pre-release lines suffered variable harvest losses in some locations, further analysis focuses on the response of Jade-AU⊕ to different row spacing and plant populations.

The combined analysis of 2013-14 and 2014-15 trials (a total of nine trials at six sites) (Figure 1) showed that even though site mean yields varied from 0.5 t/ha to over 2.0 t/ha, there was a consistent and positive response to row spacing in SQ. However, in CQ there was no response to row spacing, partly due to poor yields (0.7 + 0.2 t/ha).

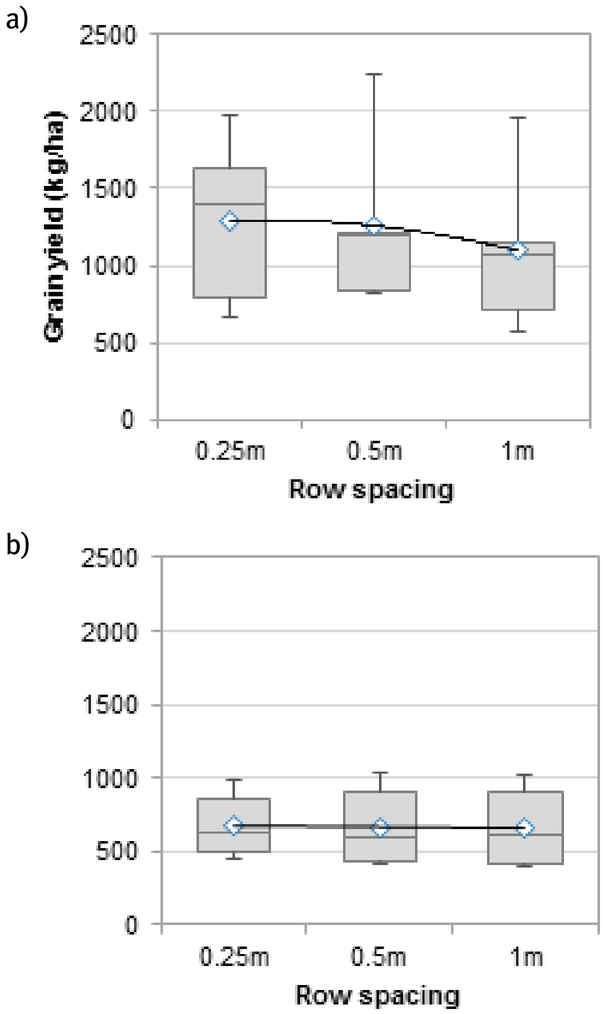


Figure 1. Comparative analysis of the effects of row spacing on yield of mungbean from 5 trials at 4 sites in Southern Queensland (a) 4 trials at 2 sites in Central Queensland (b). The data is drawn from the 2013-14 and 2014-15 summer trials. The box represents 75% of the variability in the data, whiskers indicate maximum and minimum values and the cross line indicate median and the diamond in the box indicate the mean of the data

Overall there was no significant yield difference between 0.5 m and 0.25 m row spacings.

The reasons for higher yields from narrow row treatments was examined in detail at selected sites by measuring light interception at all row configurations and soil water use in 0.25 m and 1.00 m plots. The intercepted light measured periodically in different row spacing treatments at Warra site (2014-15 summer) showed that the narrow rows were able to intercept more solar radiation consistently from flowering through pod filling compared to 1.00 m rows (Table 1).

Table 1. Mean intercepted radiation (LI%) measured in different row spacing treatments for Jade-AU⁽ᴾ⁾ at Warra site during 2014-15 summer recorded days after sowing (DAS). Letters indicate significant differences. Values with like letters are not different

Row Spacing	LI% 5-2-2015 (44DAS)	LI %17-2-2015 (56 DAS)	LI% 4-3-2015 (71 DAS)	Average LI%
1.00m	74 b	70 b	57 b	67
0.50m	94 a	91 a	60 ba	82
0.25m	92 a	90 a	66 a	82
Sig	P<0.001	P<0.001	P<0.001	

It was clear that narrow rows rapidly developed their canopies as indicated by greater light interception and maintained the canopy throughout the crop growth compared to wide rows. The rapid canopy closure might also have reduced soil evaporation, thus enabling plants to draw soil moisture from inter-row space more effectively, compared to plants on 1.00 m row spacing.

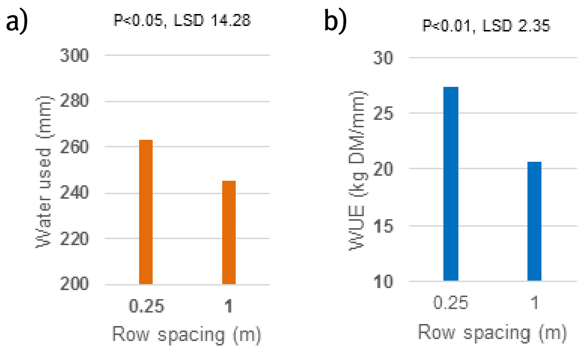


Figure 2. Total soil water used (a) and water use efficiency (b) by mungbean plants by 0.25 m and 1m rows at Warra site during the 2014-15 summers

The data on soil water measurements made at planting and harvest time plus in-crop rain provide some insights into the water used by plants in narrow and wide rows. It was clear that plants on narrow rows were able to extract 20 mm more water compared to plants on 1.00 m rows, even though both treatments received the same amount of in-crop rain (Figure 2). It appears the plants on 0.25 m row spacing were able to access water in between the row more effectively compared to plants on 1.00 m row spacing. There is little information about the root architecture and water extraction pattern of mungbean in different row spacings.

The plants in 0.25 m rows also had significantly higher water use efficiency (WUE) compared to plants in 1.00 m rows (Figure 2). The mechanism underpinning the higher WUE in narrow rows requires more research.

Table 2. Summary of results from row spacing trials in mungbean conducted in Central Queensland and Southern Queensland region during 2013-14 and 2014-15 summer seasons. (NS = not significant; * = p< 0.05; ** = P< 0.01; *** = P < 0.001)

Analyses	Site	Row spacing (0.25, 0.50 and 1.00 m)	Site x Row spacing	Variety	Site x Variety	Row spacing x Variety	Site x Row spacing x Variety
CQ (2 sites,2 years, Crystal⏀ Jade-AU⏀)	***	NS	*	***	*	*	NS
SQ (3 sites, 2 years, Jade-AU⏀ only	***	**	NS				
Across SQ and CQ, 2 years, Crystal⏀ and Jade-AU⏀ (7 trials)	***	*	***	***	NS	NS	NS
Across SQ and CQ, 2 years, Jade-AU⏀ only(9 Trials)	***	**	*				

Table 2 summaries row spacing experiments conducted during the 2013-14 and 2014-15 seasons across locations.

Site by row spacing effects were significant in CQ but not in SQ, but became significant when data for CQ and SQ was combined for analysis, again proving that CQ behaves differently compared to SQ in terms of plant response to management. Varietal significance is because of superior performance of Jade-AU⏀ over Crystal⏀ in both SQ and CQ environments.

Plant population effects

As row spacing by plant population interactions were not significant, the effects of plant population on yields were investigated at 0.50 m row spacing across sites. Although experimental plant populations were aimed at achieving 10, 20, 30 and 40 plants/m^2 the plant stand measured at the time of dry matter cuts varied at some sites, as a result measured plant counts were used as a continuous variable to assess yield response against at each site (Figure 3).

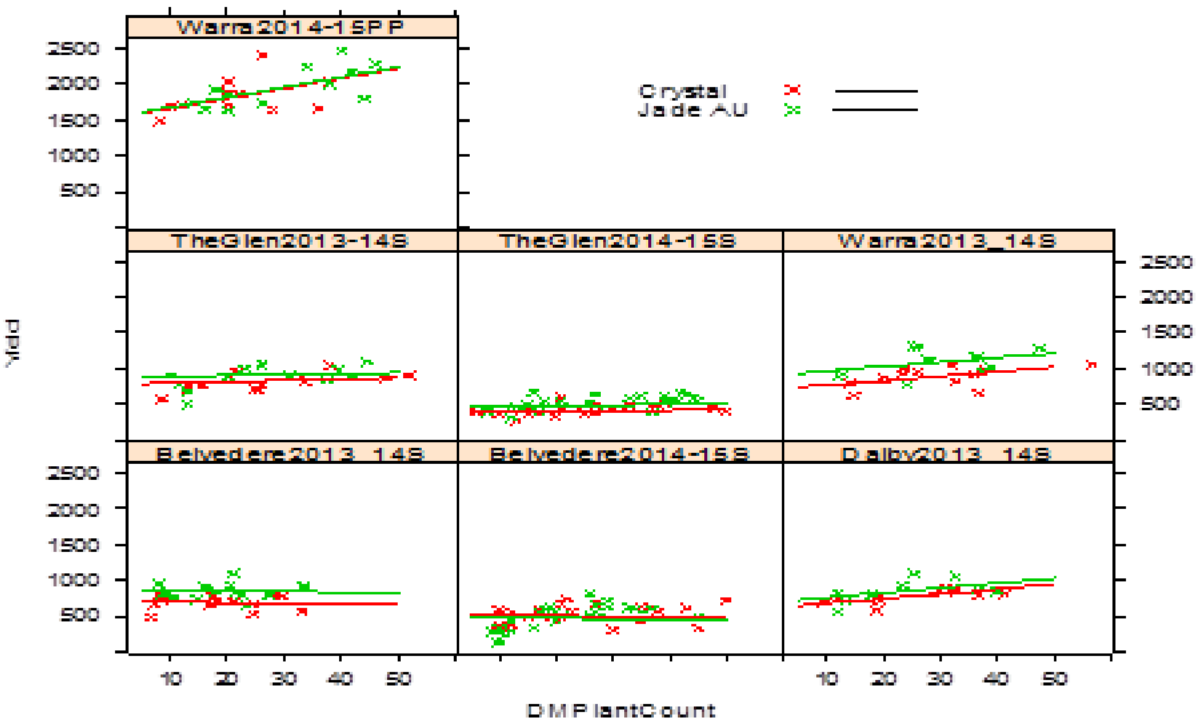


Figure 3. Plant population response for Jade-AU⏀ and Crystal⏀ measured at 7 trials (4 sites) across 2013-14 and 2014-15 summer seasons. Note: 'The Glen' is a property near Capella, and 'Belvedere' is a property near Baralaba.

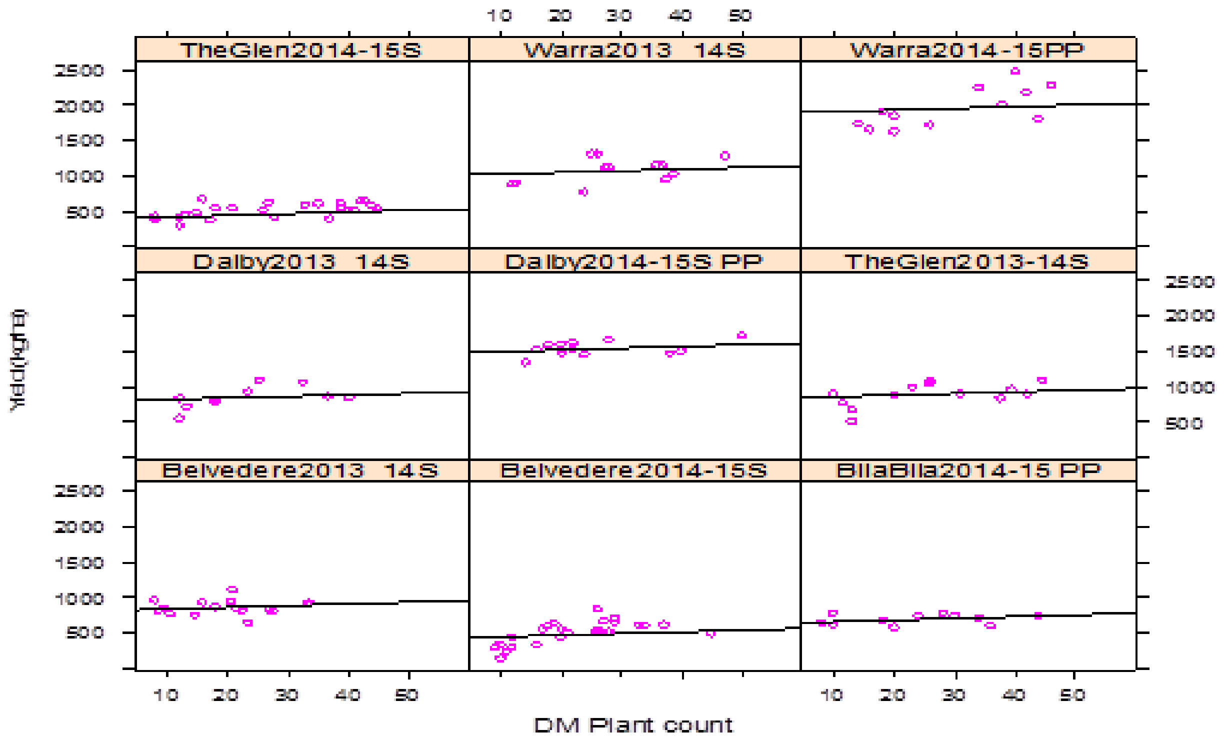


Figure 4: Yield responses to plant population from trials conducted during the 2013-14 and 2014-15 seasons, across all 9 sites (5 in Southern Queensland and 4 in Central Queensland) for Jade-AU⁽ᴾ⁾ only. Note: 'The Glen' is a property near Capella, and 'Belvedere' is a property near Baralaba.

Figure 4 shows the yield data against plant population measured by dry matter (DM) sampling at each site. There was a significant effect on yield for the site by variety interaction (Fprob<0.001) and site by plant count interaction (Fprob=0.005) – indicating separate slopes for each site, but parallel for variety. There were significant responses of plant population for SQ trials.

Plant population effects are significant mainly because of lower yields from low plant populations (<20 plants/m²). The yields from 20, 30 and 40 plants/m² were not significantly different.

Statistical summary of the effects of plant population on yields is presented in Table 3.

Implications for growers

Summary of row spacing trials conducted across the two seasons showed effects were not significant in CQ but significant in SQ sites. When the data across the regions was analysed collectively the 0.50 m or below row spacings were better.

As indicated earlier, plant population effects are significant mainly because of lower yields from low plant populations (<20 plants/m²). The yields from 20, 30 and 40 plants/m² were not significantly different so current recommendations for commercial varieties remain appropriate.

Table 3. Summary of results from plant population trials in mungbean conducted in Central Queensland and Southern Queensland region during 2013-14 and 2014-15 summer seasons. (NS = not significant; * = p< 0.05; ** = P< 0.01; *** = P < 0.001)

Analyses	Site	DM plant population (measured)	Site x Plant population	Variety	Site x Variety	Plant pop x Variety	Site x Plant pop x Variety
CQ (2 sites,2 years, Crystal⁽ᴾ⁾ Jade-AU⁽ᴾ⁾)	***	NS	NS	***	*	NS	NS
SQ (3 sites, 2 years, Jade-AU⁽ᴾ⁾ only	***	**	NS				
Across SQ and CQ, 2 years, Crystal⁽ᴾ⁾ and Jade-AU⁽ᴾ⁾ (7 trials)	***	*	** (SQ) NS (CQ)	***	***	NS	NS
Across SQ and CQ, 2 years, Jade-AU⁽ᴾ⁾ only (9 trials)	***	**	NS				

The data generated in the last two years gave some valuable insights into understanding how a mungbean crop is reacting to management changes in different environments.

Generally the narrower row spacings of 0.25 and 0.50 m are maximising yield. This is in contrast to conventional thinking that in dry seasons wide row spacings assist in conserving moisture until late in the season to ensure grain fill. There are still some questions to be answered with regards to pest and disease spread and control in narrow rows, and harvestability of the different row configurations.

The plant population trials generally confirmed current recommendations of plant populations between 20 and 30 plants/m², particularly with the larger seeded varieties. Jade-AU⊕ was the best performing variety which is to be expected as it is the most recent large seeded release from the mungbean breeding program.

The row spacing and plant population trials were used not only to validate the current management practices implemented by growers, but also to generate data on biomass and yield across trials and regions.

A synthesis of two years trials showed that there is a strong and linear relationship between dry matter and yield in mungbean (Figure 5).

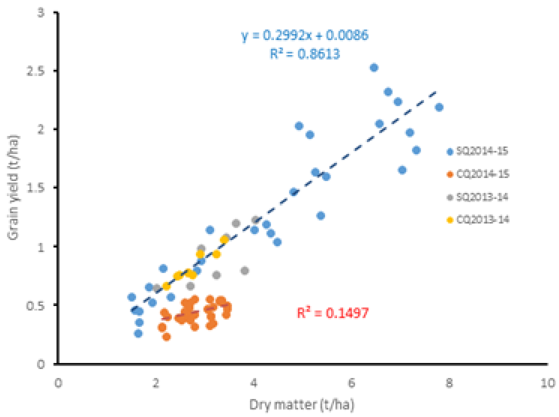


Figure 5: Relationship between dry matter and yield in different growing environments and management treatments. The data is drawn from trials conducted during 2013-14, 2014-15 summers.

A tight relationship between DM and grain yield in mungbean indicates that the harvest index of 0.3 (as indicated by the slope) is a conservative figure and any varietal and management practice that increases crop biomass will also increase grain yield. Most of the project's trials (and farmer crops) achieve 4 t of DM and up to 1.25 t/ha yield. The data from CQ (orange) is at the bottom of the regression showing how poor the yields were in CQ.

Further work on rooting depth and water extraction in upcoming seasons may help to explain some of the variability in yield that has been found to date.

Acknowledgements

Many thanks must go to the trial co-operators at Capella, Baralaba, Miles, Warra, Dalby and Billa Billa and also to the Grains Research and Development Corporation, the Queensland Alliance for Agricultural and Food Innovation and the Department of Agriculture and Fisheries, for funding the project.

Trial details

Location:	Capella, Baralaba, Miles, Warra, Dalby and Billa Billa
Soil type:	Capella: black/grey cracking vertosol based on open iron bark sloping plains
	Baralaba: black/grey cracking vertosol based on brigalow alluvial flood plains
	Miles: grey vertosol
	Warra: grey vertosol
	Dalby: black cracking clay
	Billa Billa: grey vertosol
In-crop rainfall:	Capella: 28 mm
	Baralaba: 261 mm
	Miles: 270.6 mm (hence the waterlogging)
	Warra: 154 mm
	Dalby: 109.2 mm
	Billa Billa: 107 mm
Fertiliser:	Starter fertiliser 50 kg/ha

Mungbean yield response from pre-plant nitrogen applications - Central Queensland

Doug Sands and James Hagan
Department of Agriculture and Fisheries

Research Question: *Is the yield of mungbean improved by additional nitrogen application prior to planting?*

Key findings

1. Limited response to pre-plant application of nitrogen in mungbean
2. Generally low yielding crop sites where weather conditions dominated crop responses
3. Small response to background compound fertiliser containing phosphorous, potassium and sulphur at one site

Background

Mungbean crops develop more rapidly in Central Queensland (CQ) than in southern growing regions. In CQ, mungbean crops typically flower in 32 to 34 days rather than the 42 to 45 days in southern regions; and crops may be ready to harvest after 75 rather than 90 days. This speed of development puts pressure on plants to build their vegetative resources quickly. The mungbean root system is also put under pressure by this relatively short vegetative period as plants devote some of their energy to maintain rhizobia and their symbiotic capacity to fix nitrogen (N).

Some grower experiences have suggested that the plant can achieve a greater biomass in a shorter period if it has access to readily available nitrates in the soil profile instead of having to fix its own N. Higher biomass production has generally meant higher yield potential for mungbean crops. This experiment was developed to test whether mungbeans could utilise applied N to build greater biomass and therefore a higher yield potential when planted in relatively low N situations.

Treatments

This experiment was carried out at two sites that were co-located with row spacing and population trials. The first site was near Capella, approximately 30 km north of Emerald. The second site was located south-east of Baralaba.

The fertiliser treatments were put down at the Capella site on the 28 November 2014 and the mungbean crop was planted 28 January 2015. At Baralaba, the fertiliser treatments were put down 4 December 2014 and the mungbean crop was planted 12 February 2015. Eight treatments were applied at each site with an extra 0N plot included to give nine plots per replicate (Table 1). The two 0N plots within each replicate would give an indication of the inherent variability within the site and also provide a stronger baseline mean for the experiment. The treatments consisted of a series of N rates applied as urea, with background nutrients simultaneously applied using a commercial blended product (CK55S) at a rate of 140 kg/ha and liquid zinc (Zn) product applied at the equivalent of 1 kg Zn/ha.

Table 1. Nutrient breakdown of treatment labels for mungbean nitrogen trials

Label	N rate (Urea) kg/ha	P rate (CK55S) kg/ha	K rate (CK55S) kg/ha	S rate (CK55S) kg/ha	Zn (Chelated liquid) kg/ha
0N	0	20	17	9	1
0N	0	20	17	9	1
40N	40	20	17	9	1
60N	60	20	17	9	1
80N	80	20	17	9	1
120N	120	20	17	9	1
0N-PKS	0	0	0	0	1
120N-PKS	120	0	0	0	1
FR	0	0	0	0	0

Note: Nitrogen (N), Phosphorus (P), Potassium (K), Sulfur (S), Zinc (Zn)

The plots labelled FR (Farmer reference) received no fertiliser and were not ripped by the fertiliser applicator. The plots labelled 0N-PKS had no fertiliser applied except liquid Zn but they were ripped by the fertiliser applicator. These two treatments (FR, 0N-PKS) should identify the impact that ripping the soil down to 20 cm has on its own with no additional fertiliser.

The treatments were applied as bands 50 cm apart with the background nutrition applied at a depth of 20 cm and the N applied at 10 cm. The mungbean crop was planted on 50 cm rows at a population of 25 plants/m² with starterZ applied with the seed at a rate of 30 kg/ha. These mungbean rows were very close to the same alignment as the bands of fertiliser. Jade-AU⟨D⟩ was the only variety used in these trials. Plots were 24 m long and 4 m wide. Four replicates were used for a total of 36 plots in each trial.

The crop at the Baralaba site received 261 mm of in-crop rainfall, with nearly half (125 mm) occurring one week after planting. The Capella site received only 28 mm of in-crop rainfall.

Total biomass samples were cut at maximum dry matter accumulation or 90% black pod. Grain yields were measured by harvesting two strips out of each plot with a plot harvester and weighed separately. Grain yields were adjusted for moisture to a standard of 12.5%.

Results

Despite being planted on a full profile of soil moisture, the dry season with only 28 mm in-crop rain, may have limited yields and made it difficult to identify significant differences between treatments at the Capella site (Table 2). The only significant differences were between the middle nitrogen rates (60N, 80N), and the FR and the treatments with no background fertiliser (0N-PKS, 120N-PKS). There were no significant differences between any of the N rates (0N, 40N, 60N, 80N, 120N). It is worth noting that this site had 67 kg/ha of nitrate N down to 120 cm available at planting (see Trial details), which may have influenced the response to additional fertiliser N.

Table 2. Yield and Dry Matter results for nitrogen response trial at Capella

Treatments	DM Yield (kg/ha)	Grain Yield (kg/ha)	Relative difference from FR plots (kg/ha)	Relative difference from FR plots (%)
FR	3141	533 a	0	0
0N-PKS	2961	567 ab	34	6
0N	3126	587 abc	54	10
40N	3073	595 abc	62	12
60N	3359	648 c	116	22
80N	3579	638 c	105	20
120N	3141	632 bc	100	19
120N-PKS	3406	592 abc	59	11

Means with the same letter are not significantly different at the 5% level. There were no significant differences in the DM yields

The main response in this trial was to the combined background phosphorus, potassium and sulphur fertiliser rather than any of the nitrogen rates. This response was also evident in the co-located 'population X variety' trial at the site. There was no significant yield effect from deep ripping on its own (i.e. between the FR plots and the 0N-PKS plots).

At an application cost of $30/ha for deep application of nutrients, urea at $400/t, CK55S at $960/t and a mungbean farm gate price of $1100/t none of the background nutrition treatments were profitable in year one (Table 3). It would be expected that 20 kg P/ha would provide benefits for more than one year so it is possible that these treatments may return positive net benefits in future years.

Table 3. Economics of background nutrients and applied nitrogen in mungbean at Capella

Treatments	Treatment Cost ($/ha)	Treatment Benefit vs FR ($/ha)	Net Benefit ($/ha)	Return on Investment (ROI)
FR	0	0	0	0.0
0N-PKS	30	37	7	0.2
0N	117	60	-58	-0.5
40N	148	69	-79	-0.5
60N	163	127	-36	-0.2
80N	178	116	-63	-0.4
120N	209	109	-99	-0.5

The trial at Baralaba also showed no significant difference in grain yields or in dry matter production (Table 4). Yields were again low despite receiving 261 mm of in-crop rainfall. Indeed, waterlogging from 125 mm of rainfall over three days, just one week after planting, may have compromised the yield potential. However, the low yields make it difficult to measure significant treatment differences. Available nitrate N down to 120 cm at planting was 64 kg N/ha (see Trial details), which may also have reduced possible nitrogen responses.

Using the same prices as the Capella analysis, none of the treatments returned a positive net benefit in year one; with losses ranging from -26 to -$128/ha compared to farmer reference treatments (Table 5). It would be expected that the deep nutrition of phosphorus and potassium will have longer lasting effects so may provide positive returns in the longer term.

Table 4. Yield and Dry Matter results for nitrogen response trial at Baralaba

Treatments	*DM Yield (kg/ha)	*Grain Yield (kg/ha)	Relative difference from FR plots (kg/ha)	Relative difference from FR plots (%)
FR	3056	401	0	0
0N-PKS	3044	406	5	1
0N	3280	464	63	14
40N	3270	480	79	16
60N	3491	456	55	12
80N	3436	503	103	20
120N	3440	475	74	16
120N-PKS	3258	407	6	2

*No significant differences in the means for total dry matter or grain yield at the 5% level.
l.s.d grain yield = 107, l.s.d dry matter = 462

Table 5. Economics of background nutrients and applied nitrogen in mungbean at Baralaba

Treatments	Treatment Cost ($/ha)	Treatment Benefit vs FR ($/ha)	Net Benefit ($/ha)	ROI
FR	0	0	0	0.0
0N-PKS	31	6	-26	-0.8
0N	119	69	-49	-0.4
40N	149	87	-62	-0.4
60N	164	61	-103	-0.6
80N	180	113	-67	-0.4
120N	210	82	-128	-0.6
120N-PKS	123	7	-116	-0.9

Implications for growers

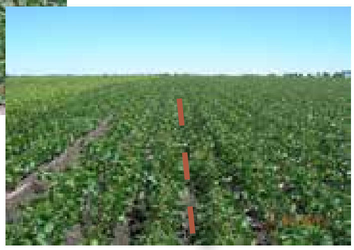
These results suggest that additional nitrogen may not increase the biomass and the grain yield of mungbeans in CQ environments when profile nitrogen is above 60 kg/ha. However, this suggestion is based on just two low yielding trials (one from waterlogging, one from dry conditions) and further research is needed over a number of seasons to consolidate the data set and build confidence in the local results.

Acknowledgements

Thank you to the trial co-operators for hosting these trials.

The Queensland Pulse Agronomy Initiative is funded by the Grains Research and Development Corporation, the Queensland Alliance for Agricultural and Food Innovation and the Department of Agriculture and Fisheries.

Baralaba trial site, 60N plot on right, 0N plot on left (foreground)



Capella site, first row of plots for nitrogen trial on the right of red line.

Trial details

Location: Trial 1 – Capella,
Trial 2 –Baralaba

Crop: Mungbeans (CV Jade-AU⁽ᵖ⁾)

Soil type: Capella – Black/grey cracking vertosols based on open iron bark sloping plains

Baralaba – Black/grey cracking vertosols based on brigalow alluvial flood plains

In-crop rainfall: Capella 28 mm

Baralaba 261 mm

Fertiliser: Starter Z at planting with the seed @ 30 kg/ha.

Selected soil characteristics for nitrogen response sites:

	Depth (cm)	Col P (mg/kg)	BSES P (mg/kg)	PBI	Exc. K (meq /100g)	ECEC (meq /100g)	Sul - KCl40 (mg/kg)	N - No3 (mg/kg)
Capella	0-10	13	28	128	0.35	58	3.4	6
	10-30	2	16	139	0.16	60	3.6	8
	30-60	1	17	141	0.13	62	3.6	6
	60-90	n/a	n/a	n/a	n/a	n/a	n/a	4
	90-120	n/a	n/a	n/a	n/a	n/a	n/a	2
Baralaba	0-10	12	18	91	0.46	30	2.5	8
	10-30	3	5	100	0.26	33	3.2	5
	30-60	1	7	102	0.23	33	10.2	4
	60-90	n/a	n/a	n/a	n/a	n/a	n/a	2
	90-120	n/a	n/a	n/a	n/a	n/a	n/a	3

*Profile nitrogen to 120cm: Capella 67kg/ha, Baralaba 64kg/ha.

Mungbean preliminary trial investigating varietal response to applied irrigation deficits – St George

Grant Cutler
Department of Agriculture and Fisheries

***Research Question:** Do mungbeans respond to an early irrigation event during the vegetative stage, and is there a varietal response to this? | To what extent does this extra irrigation event affect the crops water-use efficiency indices?*

Key findings

1. Yields were found to increase with the early irrigation event whilst not affecting crop time to flowering or maturity
2. Varietal responses were similar across both treatments
3. Gross production water-use index and Crop water-use index was found to increase with the early irrigation event whilst maintaining Irrigation water-use index

Background

Mungbeans have been widely planted under irrigation in South-Western Queensland. However they can be frequently exposed to periods of high heat during flowering and pod formation which ultimately limits yields under irrigated situations. Given their current high prices, the area planted to mungbeans has increased and growers are seeking the best possible returns per mega litre of water applied.

Current commercial practice for mungbeans dictates two irrigation events, one at flower initiation and the other at peak flowering (roughly 10-14 days post first irrigation). Anecdotally, this seems the best practice to ensure the crop's water requirement is satisfied whilst using the minimum amount of irrigation water. Some producers may even split the last irrigation event into two small events as a result of hot weather to minimise flower drop during peak flowering. This preliminary trial was undertaken to investigate the effect of a mid-vegetative irrigation event on three commercial varieties and their water-use efficiency indices.

Treatments

- Early irrigation applied mid vegetative stage, followed by two applications at flower initiation and peak flowering
- Commercial practice – an application at flower initiation, and another at peak flowering
- Varieties – Jade-AU$^{\Phi}$, Crystal$^{\Phi}$, Celera-II-AU$^{\Phi}$

Results

The results from this preliminary trial show that yield can be improved with an extra irrigation event being applied during the mid-vegetative stage. Plants within the three irrigation treatment produced a greater biomass more quickly, but resulted in the same harvest index as the two water commercial treatment. The resulting faster plant growth had no effect on crop time to flowering or time to maturity given both treatments received their last irrigation at peak flowering. Data recorded from the soil moisture capacitance probes throughout the trial showed that, by the end of the season, the plants that had received the commercial treatment of two irrigations were extracting water down to a depth of 1 m, and had extracted more moisture from depth compared to the three irrigation treatment which had developed a root system to 90 cm depth, but used more water due to the additional growth and extra irrigation event.

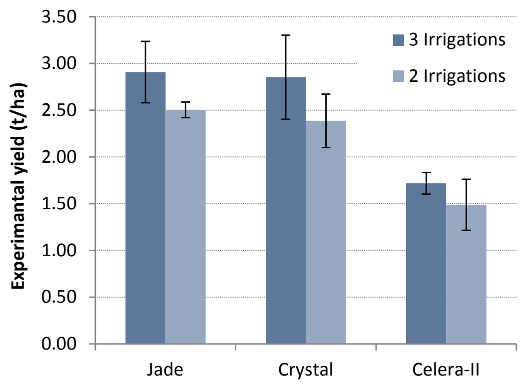


Figure 1. Experimental yield of varieties grown under two irrigation strategies

The majority of the yield increase between the two irrigation treatments can be attributed to the greater biomass grown by the three irrigation treatment, leading to more flower/fruiting sites and greater yield. Moisture probe data showed that the commercial irrigation treatment (two irrigations) was extracting water to a greater depth later in the season, causing the plant to work harder and not fill fruiting sites, especially during periods of high heat at flowering. Table 1 shows that all water-use efficiency indices increased with the extra irrigation during the vegetative stage. The irrigated water-use index (IWUI) remained roughly the same for both treatments, showing that, although the three irrigations used more water, its efficiency in turning that water into yield was only slightly higher than the two irrigation commercial treatment. This in turn led to a higher gross production water-use index (GPWUI) and crop water-use index (CWUI). Another major benefit of the early irrigation treatment was minimising the soil-water deficit for the following irrigation events, resulting in quicker irrigation run times and less waterlogging.

Table 1. Water-use efficiency indices for irrigation treatments

Number of irrigations	GPWUI		IWUI		CWUI	
	t/ML	$/ML	t/ML	$/ML	kg/mm	$/mm
3	0.86	$946	1.39	$1529	8.57	$9.43
2	0.79	$869	1.35	$1485	7.88	$8.67

Note: Gross return calculation using WaterSCHED2 based on a unit price of $1,100/t whilst the excluding variable harvest costs for a 50ha paddock
GPWUI: crop yield/total water available to crop (soil PAW, rainfall & irrigation)
IWUI: crop yield/total irrigation applied
CWUI: crop yield/crop evapotranspiration (ETc)

Implications for growers

This preliminary trial suggests that two irrigations (current commercial practice) can produce a high yielding crop. Where there is inadequate rainfall for early season growth it may be beneficial to apply an extra irrigation during the mid-vegetative stage. An extra irrigation early in the season has the ability to increase GPWUI and CWUI whilst maintaining the IWUI, essentially producing slightly more crop with the same irrigated water-use. When applying any water to a mungbean crop it's best to optimise the irrigation event by applying the water as quickly as possible and to minimising the amount of tail water through early cut-off times. This will minimise the possibility of waterlogging.

Acknowledgements

The irrigation team would like to thank the host of this trial.

This trial was conducted under the 'Improved economic productivity from irrigated agriculture in the Queensland Murray-Darling Basin' project funded by the Australian Government under the Murray-Darling Basin Regional Economic Diversification Program.

Trial details

Location:	St George, Queensland
Crop:	Mungbean
Soil type:	Grey vertosol

Irrigation being applied to late water treatment, note the early water treatment represented by the bright-green strip

Chickpea row spacing x population - Central Queensland

Doug Sands
Department of Agriculture and Fisheries

***Research Question:** Does planting chickpeas in different spatial configurations increase yield in Central Queensland conditions?*

Key findings

1. There was limited impact on yield from changing population
2. There was little impact on yield by changing row spacing although the wider rows had a small increase (8.5%) at one site
3. Narrow rows created the most dry matter production but the least grain yield

Background

The Queensland Pulse Agronomy Initiative has been examining the concept of whether changing the plants' spatial positioning in the paddock has any effect on the physiology of the plants growth characteristics within its climatic environment (environment X management). The best way to do this is by changing row spacing and population. These trials have been carried out across both chickpeas and mungbeans which are the dominant pulses in Central Queensland (CQ). For the 2015 winter season, four trials were planted at Theodore and Baralaba. These trials were planted within paddocks that growers were planting chickpeas at the same time.

Treatments

Each trial had a factorial structure with each of the four row spacing treatments being broken up into three different populations. Each trial was planted with the one variety. Table 1 summarises the details of each of the four trials.

Table 1. Trial details

Site	Variety	Row Spacing (cm)	Target Population (plants/m²)	Reps
Baralaba	Kyabra⊕	25, 50, 75, 100	10, 25, 40	3
Baralaba	CICA912	25, 50, 75, 100	10, 25, 40	3
Theodore	Kyabra⊕	25, 50, 75, 100	10, 25, 40	3
Theodore	CICA912	25, 50, 75, 100	10, 25, 40	3

All treatments were planted with Starter Z at 30 kg/ha. Information collected included: plant counts, dry matter weights, grain weights, soil moisture and flowering dates.

Soil tests were conducted at planting for both sites. Table 2 summarises some of the general site information.

The Theodore site is a cracking brigalow clay on upland slopes with a degraded gravel substrate layer at about 100 cm deep. The soil has rising salinity at a depth of 90-120 cm which may be mainly due to rising sulfur levels. Sodium also increases with depth with the Exchangeable Sodium Percentage (ESP) rising to 11.6% in the 30-60 cm layer. This may restrict rooting depth of chickpeas. Phosphorus (P) levels drop off considerably in the 10-30 cm zone with a Colwell phosphorus of 3 mg/kg.

The Baralaba site is also a cracking brigalow clay but based on an alluvial flood plain which means it has no physical impediments at depth of profile. However it also has rising salinity between 90-120 cm and this again could be attributed to rising levels of sulfur in the profile. Sodium is also an issue at depth with the ESP rising to 8.5% in the 30-60 cm layer. This again may restrict rooting depth of chickpeas and phosphorus levels are also low in the 10-30 cm zone with a Colwell P of 3 mg/kg.

Table 2. Summary of site

Site	PAWC 0-120cm (mm)	Rainfall	Starting N 0-120cm (kg/ha)	Planting date	Days to maturity
Theodore	90	107	127	26/5/15	112
Baralaba	99	97	56	21/5/15	111

Results

Theodore trial site

The data shown in Figures 1 and 2 is an average of the two trials on site; even though there was a different variety for each trial. Due to the structure of the trial site, reps for each trial were placed side by side and this has allowed the biometry team to combine the data together for analysis.

Figure 1 shows the only significant difference in dry matter (DM) yield was for the narrow row spacing (25 cm, F pr = 0.027) of 504 kg/ha (15.8%). There were no significant differences between the other three row spacings. There are also no significant differences in DM production between populations, indicating the plant can compensate quite effectively in relation to DM, and possibly canopy cover, within this population range.

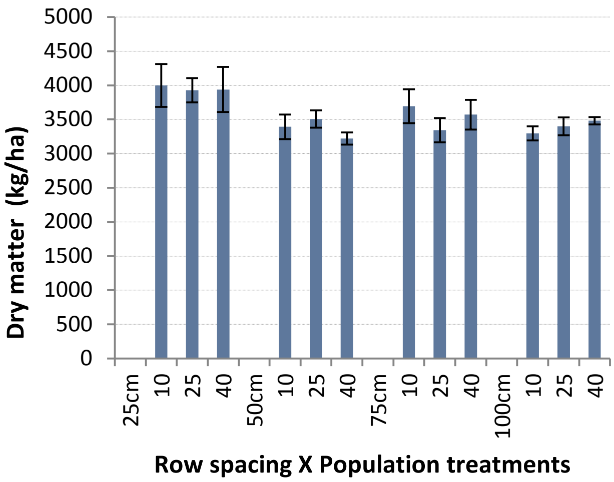


Figure 1. Chickpea dry matter production for row spacing (cm) X population (plants/m²) trials (Theodore)

The data in Figure 2 shows significant responses in grain yield to variety (F pr = 0.019), row spacing (F pr = 0.015) and population (F pr = 0.012). In these cases the differences are not large. On average across all treatments Kyabra⦶ out yielded CICA912 by 205 kg/ha (approx. 14 %). It is useful to note that Kyabra⦶ seemed to be far more consistent across the different row spacing/population combinations, whereas CICA912 performance was a little more variable across the same treatments. This may demonstrate more adaptability in the Kyabra⦶ genetics to compensate for different planting configurations.

Grain yield seems to improve with the wider row spacing although this was more delineated in the CICA912 trial then in the Kyabra⦶ trial. Overall there was an average improvement of 130 kg/ha (8.5%) for the wider rows (100 cm) against the narrow rows (25 cm). This seems to be the inverse of the DM production figures which means the wider rows have a harvest index advantage over the narrow rows as can be seen in Figure 3.

Overall there seemed to be a trend (or slope) in the yield performance of the higher plant populations across both trials, although it appeared to be more pronounced in the CICA912 trials than in the Kyabra⦶ trial. The biometric analysis shows a consistent slope for yield as population increases. On average, there is a gain of 1.737 kg/ha for each extra plant/m² within the range of populations tested. This means that the improvements in yield are quite small on a hectare basis and may not be worth consideration.

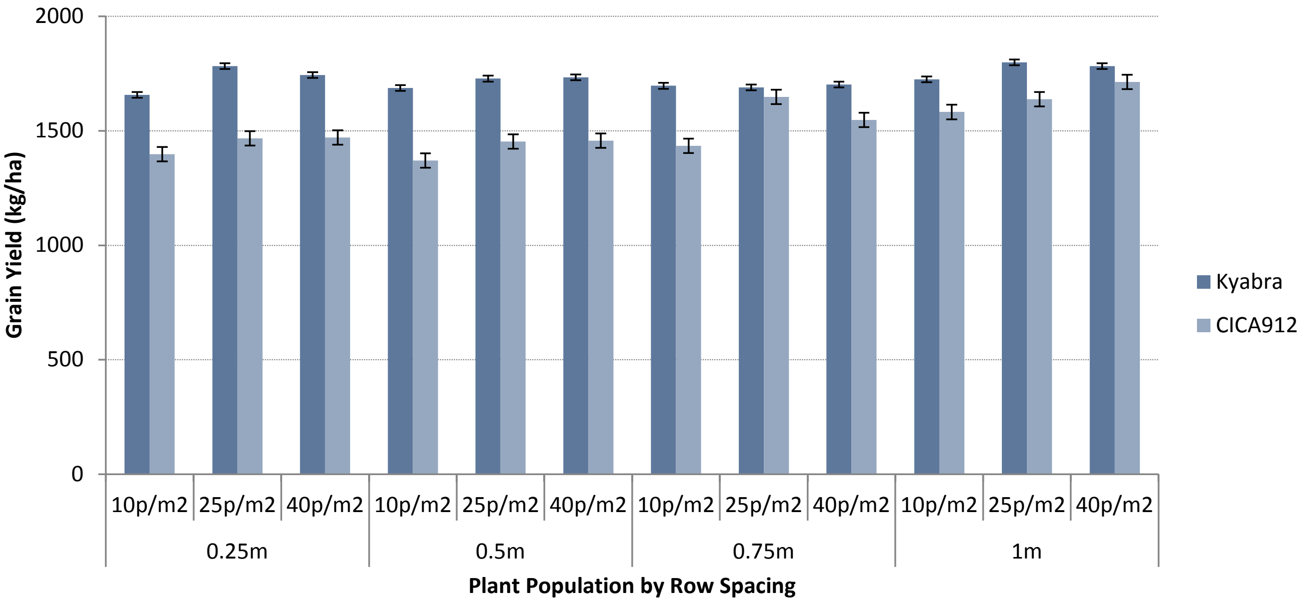


Figure 2. Chickpea grain yield for row spacing (cm) X population (plants/m²) trials (Theodore)

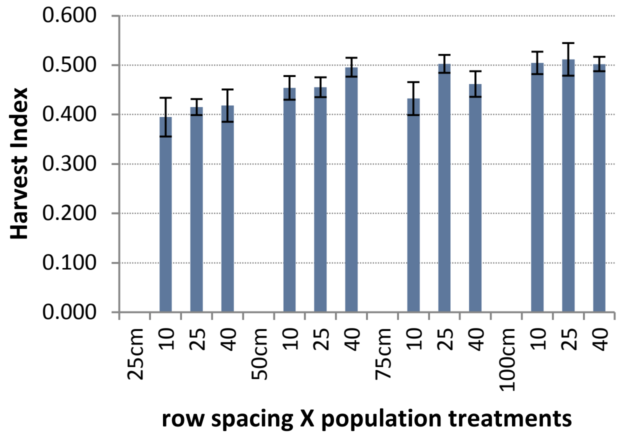


Figure 3. Chickpea harvest index for row spacing (cm) and population (plants/m^2) trials (Theodore)

The harvest index data in Figure 3 shows a significant difference between the 25 cm rows and the other configurations (F pr = 0.007). The wider rows, particularly the 100 cm rows, had a 23% advantage over the 25 cm rows in this assessment. In conjunction with data in Figure 2, the harvest index demonstrates that on this site the narrow rows have put more of its accessible resources into dry matter than into grain yield and this has made it less efficient in converting these resources into harvestable yield. The crop water use efficiency (WUE) data in Figure 7 also shows a slight improvement for wider rows although this is mainly in the CICA912 trials.

It is unclear from the data whether the inefficiency of the 25 cm rows was determined by increased dry matter production early in the crop's life or during flowering. It is possible that the 25 cm rows would utilise soil water faster by having to maintain a larger biomass. Given that the site had a soil profile that would have put restrictions on the plants' root system to forage for moisture deeper down the profile, the wider rows may have had some advantage in being able to explore wider rather than deeper for more soil water.

There was no benefit to row spacings narrower than 1 m at the Theodore site (Table 3), with the most consistent difference being varietal. The average observed difference in the better adapted Kyabra⦶ variety was 55 kg, which equalled a penalty of -$44/ha at a chickpea price of $800/t, if prices were closer to their long term average this penalty would be halved. All penalties in Kyabra⦶ were in a very narrow range, from $13 – $87/ha. There did not appear to be a linear response in the benefit for going wider in either Kyabra⦶ or CICA912.

The responses observed at the Theodore site are abnormal compared to other trials across the state, it is worth repeating the trial to determine whether it was a result of the season or soil type or some other combination of factors.

Baralaba trial site

The structure of the two trials means that the comparisons between the two varieties could not be biometrically analysed, however the following graphs will have both trials' data represented. The 100 cm treatments in the CICA912 trial were not harvested due to a planting problem causing very uneven establishment.

The data presented in Figure 4 shows no significant differences for dry matter production across the different population treatments across both trials. Similar to the Theodore data, the plant seems to be able to compensate in dry matter production adequately across the tested range of populations.

The only significant difference in row spacing was in the Kyabra⦶ trial where the 100cm rows produced up to 1380 kg/ha less dry matter than the other row spacing (F pr = 0.044). This is again similar to the Theodore trial where the wider rows produced the least amount of dry matter. This may be a result of the canopy structure of 100 cm rows where it is difficult to get full light interception across the inter-row area, whereas the narrow row configurations can achieve full canopy closure across the inter-row space and therefore proportionally the same number of plants per square metre are intercepting more sunlight and creating more dry matter.

There was no significant differences in yield across both trials (Figure 5) although this could be due to the greater variability in the data (higher standard error). Kyabra⦶ has shown again to be a little more consistent across the

Table 3. Benefit ($/ha) of narrow row spacing vs 1 m at Theodore

	0.25 m			0.5 m			0.75 m			1 m		
Variety	10/m^2	25/m^2	40/m^2	10/m^2	25/m^2	40/m^2	10/m^2	25/m^2	40/m^2	10/m^2	25/m^2	40/m^2
Kyabra⦶	-$54	-$13	-$31	-$30	-$57	-$40	-$23	-$87	-$65	0	0	0
CICA912	-$148	-$137	-$194	-$170	-$148	-$206	-$118	$8	-$133	0	0	0

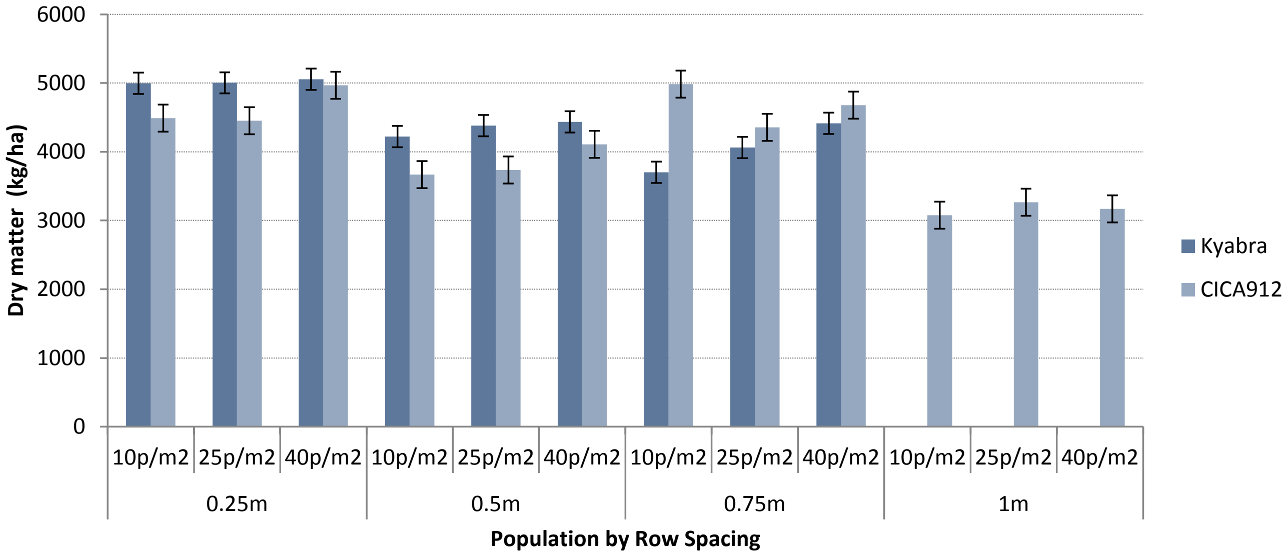


Figure 4. Chickpea dry matter production for row spacing (cm) X population (plants/m²) trials (Baralaba)

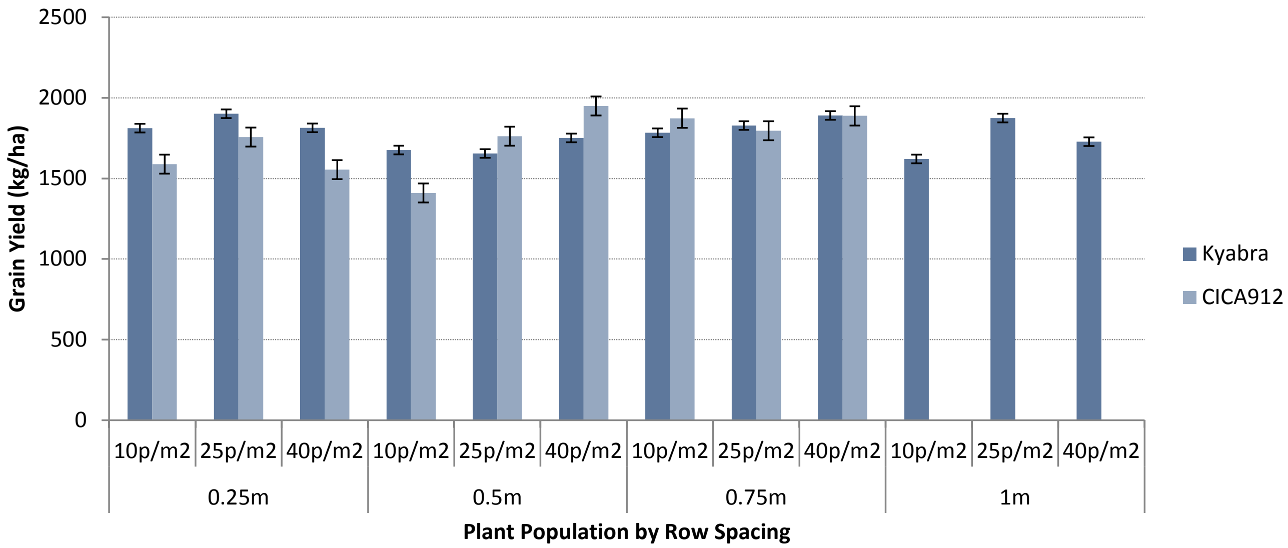


Figure 5. Chickpea grain yield for row spacing (cm) X population (plants/m²) trials (Baralaba)

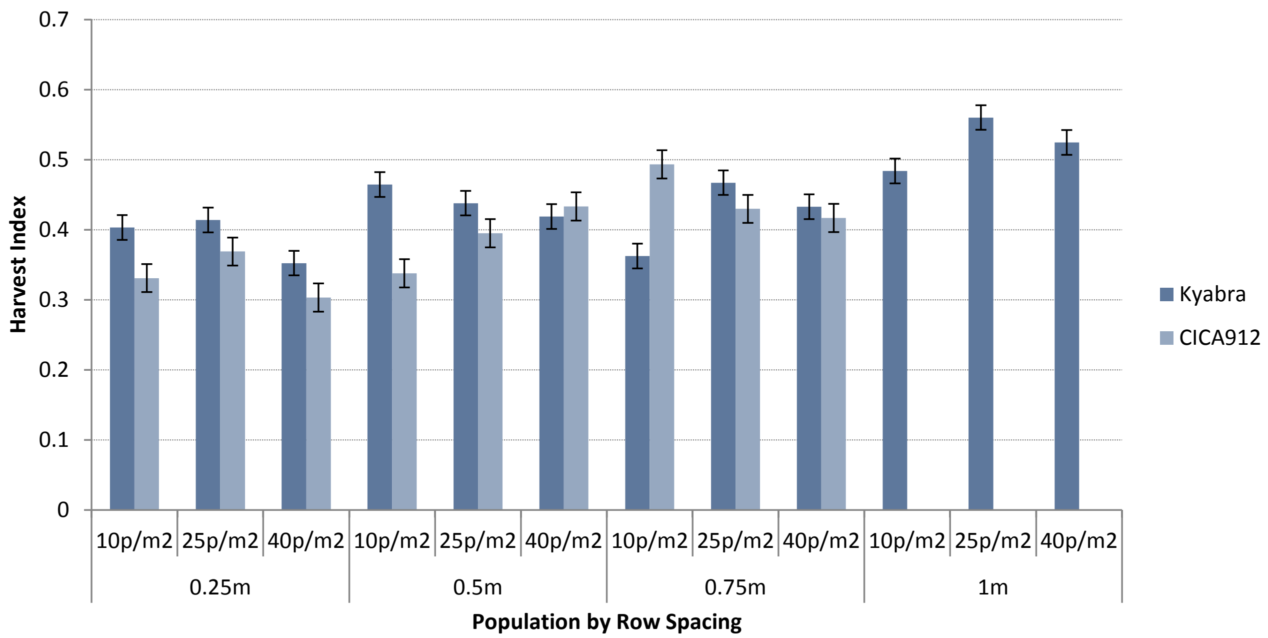


Figure 6. Chickpea harvest index for row spacing (cm) and population (plants/m²) trials (Baralaba)

row spacing treatments than the CICA912, however we do not have the data for the 100 cm rows in the CICA912 to make a fair comparison.

The only significant feature from the yield data is that there was an interaction between population and the 50 cm row spacing in the CICA912 trial (F pr = 0.021). There was a consistent slope in the yield data across the population (for an increase of 0.052 plants/m^2 equals an extra 1 kg/ha), however this was only true for the 50 cm row spacing in the CICA912 trial. For this site it would seem that row spacing and population made very little difference to overall yield; whereas the Theodore trial did show a slight advantage to the wider rows. This may be because of the Baralaba soil having fewer restrictions in its physical soil depth and a lower level of sodicity at depth allowing plants to explore a little further for resources. Dry matter production in general was greater in the Baralaba trial site (4200 kg/ha versus 3500 kg/ha) however, there was five days difference in planting date. Once again the plants have shown a great ability to compensate for spatial variability within the plant stand.

Despite the variability in the data there are no significant differences for harvest index across both trials for row spacing or population. There was a small interaction between row spacing and population in the CICA912 trial, however this was only significant for the 75 cm row treatments (F pr = 0.037). Grain yield and dry matter are the 2 components of harvest index, therefore it is not surprising that there is no significant difference in harvest index when there are no differences in dry matter (Figure 4) or grain yield (Figure 5).

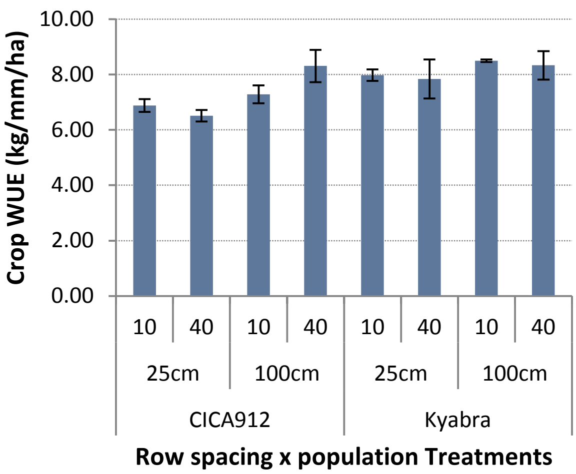


Figure 7. Chickpeas WUE to 120 cm for row spacing and population trials (Theodore)

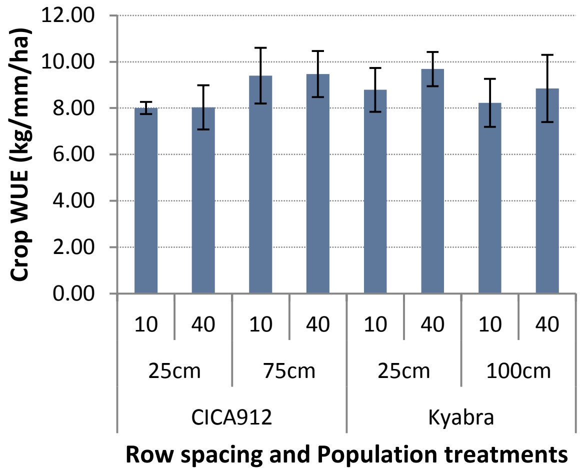


Figure 8. Chickpeas WUE to 120 cm for row spacing and population trials (Baralaba)

The crop WUE data in Figures 7 and 8 does not show any clear advantage in terms of row spacing or population. Both sites showed a lower WUE for the 25 cm row spacing in the CICA912 trials which may point to narrow rows producing more dry matter which in turn created a higher demand for transpiration and less stored moisture could be utilised for grain yield. The variable nature of crop WUE data makes it difficult to draw any major conclusions from the data except that the Baralaba site averaged a higher WUE figure than Theodore even though starting plant available water (PAW) was very similar (Table 2). This could again point to the issue of soil type and the characteristics of each soil.

As the 1 m CICA912 treatments were not harvested, the narrower treatments are being compared to 0.75 m row spacing, whilst Kyabra⊕ is being compared to the 1m row spacing treatment. On average there was no penalty to sowing Kyabra⊕ at narrower spacings, with seven out of nine treatments responding positively to being sown at less than 1 m for an average gain of $40/ha (assuming $800/t chickpeas). In contrast all except one of the CICA912 treatments suffered losses at spacings below 0.75 m, posting an average loss of almost $150/ha (Table 4).

Whilst there is no CICA912 1 m treatment to compare with the difference in response between varieties at this site it is worth investigating further, whether this is a physiological response to timing and amount of biomass production may provide growers with more confidence in variety and row spacing selection.

Table 4. Benefit ($/ha) of narrow row spacing vs 1 m at Baralaba.

	0.25m			0.5m			0.75m			1m		
Variety	10/m2	25/m2	40/m2	10/m2	25/m2	40/m2	10/m2	25/m2	40/m2	10/m2	25/m2	40/m2
Kyabra⁽ᴰ⁾	$153	$21	$69	$44	-$176	$18	$129	-$37	$130	0	0	0
CICA912	-$228	-$31	-$267	-$371	-$27	$50	0	0	0	0	0	0

Implications for growers

Overall it would seem that growers in CQ would have some flexibility in what row spacing they can grow chickpeas on without affecting average yields. While in the previous year's data there has been a slight advantage to the narrow rows and higher plant populations when yields are approaching 2.5 t/ha from sites that have been more non-limited for soil moisture and nutrition. The 2015 data would suggest in years where the climatic conditions are more limiting and the characteristic of the site is more limiting, yields of 2 t/ha or less can be achieved from nearly all row spacing under a range of plant populations; wider rows may well have a slight advantage over the narrow rows at a range of populations. Growers need to be aware of the characteristics of their soil type and what their historical yields have been before deciding on the ideal row spacing.

Acknowledgements

Thank you to our co-operators for their patience and generosity for allowing these trials to take place on their farms and supporting our work.

The Queensland Pulse Agronomy Initiative (UQ0067) is funded by the Grains Research and Development Corporation, the Queensland Alliance for Agricultural and Food Innovation and the Department of Agriculture and Fisheries.

Trial details

Location:	Baralaba[1], Theodore[2]
Crop:	Chickpeas
Soil type:	Cracking, brigalow based vertosols
In-crop rainfall:	97 mm[1], 107 mm[2]
Fertiliser:	Starter Z at planting, 30kg/ha.

Theodore (top) and Baralaba sites

Chickpea time of sowing and plant population impact on yield - Billa Billa

Rebecca Raymond and James Hagan

Department of Agriculture and Fisheries

***Research Question:** Does time of sowing or row spacing affect yield in chickpeas?*

Key findings

1. Changes in time of sowing can affect yield in chickpea depending on seasonal conditions
2. Row spacing has an effect on both yield and dry matter in chickpea

Background

Chickpea (*Cicer arietinum*) is the most adapted winter pulse crop in Queensland with the area expanding to historically high levels in 2010. Seasonal yields of chickpea range from 0.5 t/ha to 2 t/ha depending on the timing and severity of biotic and abiotic stresses during the growing season. Although yields as high as 2.5 t/ha have been achieved in varietal evaluation trials, the average yield during 2008–2011 was 1.2 t/ha.

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. Yield reliability needs to be improved in order for chickpeas to become a staple part of the farming system.

Treatments

2015 was the first year of the time of sowing (TOS) trials at the Billa Billa site however the third year of chickpea trials, as part of the Queensland Pulse Agronomy Initiative. Winter 2015 at this site saw the inclusion of TOS across four row spacings (25, 50, 75, 100 cm) with the cultivar PBA HatTrick$^{\phi}$.

The two TOS planned for the Billa Billa site were early and late within the commercial planting window for PBA HatTrick$^{\phi}$ chickpeas. The first crop was sown 14 May, with the second TOS planned one month later for 14 June. However due to high rainfall, the crop was not sown until 7 July, well outside the optimal sowing window.

The first TOS also suffered a large amount of damage from Phytophthera Root Rot (PRR) so the data for this TOS is statistically predicted based on allocating a PRR damage score to each plot.

Results

Time of sowing and row spacing effects on dry matter

Results show that there is a significant difference in dry matter between TOS1 and TOS2 with TOS1 having a significantly higher level of biomass produced in all row spacings. Consistent with other trials, the amount of dry matter declines as you widen row spacing. This however did not occur in TOS2 where there was no significant difference between the three narrower row spacings but a reduction in 100 cm (Figure 1).

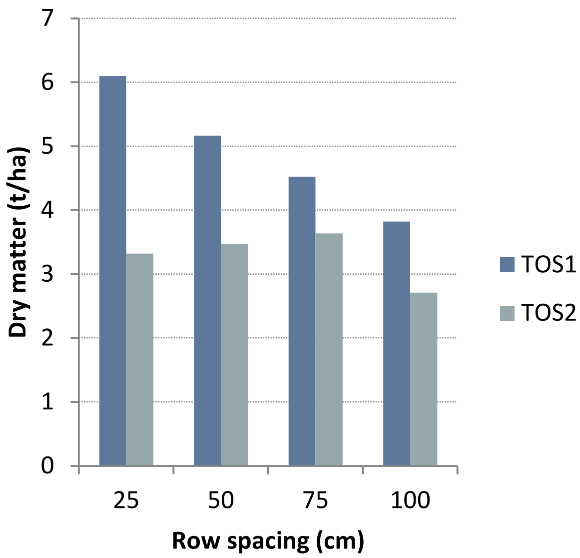


Figure 1. Effect of row spacing and time of sowing on dry matter (t/ha)

Time of sowing and row spacing effects on yield

Similarly to dry matter, TOS1 showed a significant linear decline in yield from narrow to wider row spacings. TOS2 showed the highest yield occurring at 50 cm followed by 25 cm and then 1 m. Fifty centimetre row spacing achieved twice the yield that was achieved at 1 m and a 0.5 t/ha increase over the 25 cm rows (Figure 2). *NB the yield in the TOS1 was statistically predicted according to PRR damage rating.*

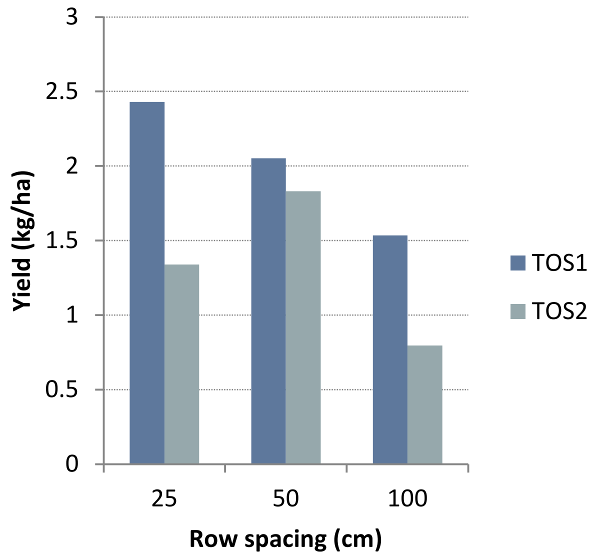


Figure 2: Effect of row spacing and TOS on yield (t/ha)

With chickpea prices at $800/t small changes in yield can greatly impact on grower returns. On average TOS1 provided a benefit of almost $550/ha over TOS 2, whilst a combination of the narrowest row spacing and TOS 1, provided an estimated benefit of over $1300/ha better return than the widest late sown treatment (Table 1).

Table 1: Economics of time of sowing vs row spacing ($/ha)

	25cm	50cm	100cm
TOS 1	$1,944	$1,641	$ 1,228
TOS 2	$1,070	$1,465	$636

Given the negligible cost of sowing in May vs June or at 25 cm vs 100 cm (some extra fuel usage), it is realistic that any additional income generated can be seen as pure profit.

Implications for growers

Winter 2015 had a very wet start which created issues particularly from PRR and also caused a delay in the planting of TOS2 which resulted in a later than optimal sowing. Each plot in the TOS1 had a PRR damage rating applied which allowed the statistician to predict a yield based on the rest of the plot and its rating score.

The season then went on to be drier than average and caused the crop to put on a large biomass but not enable it to fill grain and achieve the potential yield.

TOS1 achieved a result consistent with other trials, a linear reduction in yield and dry matter from narrow to wide row spacings whereas TOS2 had little difference in dry matter and a higher yield achieved in the 50 cm plots.

The overall yield achieved in both TOS were not significantly different however the amount of dry matter in TOS1 was significantly higher. It is thought that should the crop have received more rain later in the season, TOS1 would have achieved a higher yield as it had potential due to the large biomass. Harvest Index was better in TOS2 due to the fact it had more moisture available to set grain. It hadn't used available moisture on large biomass production and maintenance in the vegetative phase.

The results from this trial show that the TOS has not had an effect on yield due to seasonal conditions; however should the season have been more favourable we would have expected to see a higher yield in TOS1.

Acknowledgements

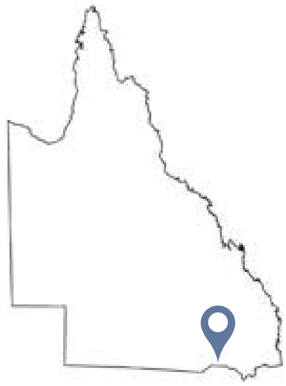
Many thanks must go to the trial co-operators, and to the Grains Research and Development Corporation, the Queensland Alliance for Agricultural and Food Innovation and the Department of Agriculture and Fisheries, for supporting the project.

Trial details

Location:	Billa Billa
Crop:	Chickpea cultivar PBA HatTrick⍉
Soil type:	Grey vertosol
In-crop rainfall:	approximately 100 mm

Fertiliser & pests were managed as part of the wider paddock.

Chickpea row spacing, plant population and irrigation impact on yield - Goondiwindi



Rebecca Raymond and James Hagan
Department of Agriculture and Fisheries

Research Question: *Do row spacing, plant population and addition of irrigation affect yield in chickpea?*

Key findings

1. Changes in row spacing can affect yield in chickpea
2. Row spacing has a larger effect on yield than plant density
3. Greater effects of the row spacing changes are seen in higher yield potential situations

Background

Chickpea (*Cicer arietinum*) is the most adapted winter pulse crop in Queensland with the area expanding to historically high levels in 2010. Seasonal yields of chickpea range from 0.5 t/ha to 2 t/ha depending on the timing and severity of biotic and abiotic stresses during the growing season. Although yields as high as 2.5 t/ha have been achieved in varietal evaluation trials, the average yield during the 2008–2011 was approximately 1.2 t/ha.

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 impacting 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.

2015 was the first year of trials at the Goondiwindi site however the third year of chickpea trials, as part of the Queensland Pulse Agronomy Initiative. Winter 2015 saw the inclusion of varied planting densities (10, 20, 30 & 40 plants/m^2) across four row spacings (25, 50, 75, 100 cm) using cultivar PBA HatTrick$^{\oplus}$, with the inclusion of an irrigated and a rain fed site within the one location.

The dryland and irrigated trial sites were located in the same field; the irrigated site positioned under the centre pivot irrigator while the dryland site was outside the area of the pivot. The trials were treated the same at sowing with identical trial layouts and fertiliser treatments. The soil tests included electromagnetic (EM) surveys which indicated that both areas were very similar in soil type and had near equal starting moistures.

Results

Row spacing effects on yield

Irrigated site

Due to good available planting moisture and early in crop rain, the irrigated site did not receive its first irrigation until 7/8 September when 15 mm was applied in two passes for a total of 30 mm. This site then received two further irrigations of the same quantity during the reproductive phase of the crop for a total irrigation amount of 90 mm (0.9 mL/ha).

Overall, good dry matter and yields were obtained at the irrigated site and significant effects of the agronomic treatments were obtained. The narrower row spacings of 25 cm and 50 cm significantly out-yielded the wider spacings of 75 cm and 100 cm in both dry matter and yield (Figure 1). It was interesting to note

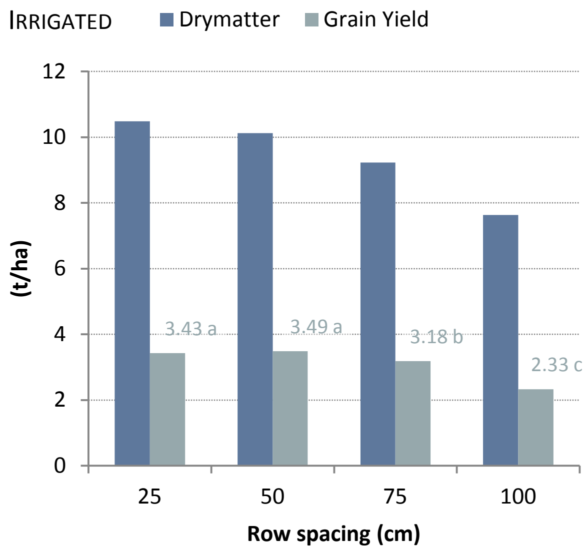


Figure 1. The effect of row spacing on yield and dry matter (irrigated)

that the three irrigations resulted in production of more than 10 t of dry matter but grain yields were less than four.

Dryland site

The dryland site produced vastly different results to the ones seen above at the irrigated site. Overall, dry matter and yields were lower and no significant effects were seen from the varying row spacing treatments with the exception of yield being significantly lower in the 100 cm treatment (Figure 2). Initial presumptions are that due to the good available water at sowing and the early in crop rainfall, the crop grew a large biomass which had a high water usage resulting in the crop running out moisture at the grain fill stage.

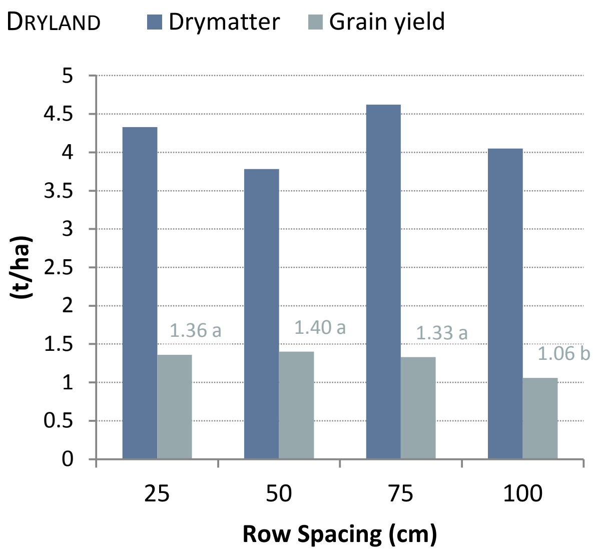


Figure 2. The effect of row spacing on dry matter and yield (dryland)

Economics of row spacing and irrigation

Irrigation provided over $1000/ha and $1100/ML benefit over dryland chickpeas (assuming $800/t) in the same paddock at all row spacings (Table 1), with the largest benefit occurring at 25 and 50 cm spacings (over $1600/ha and $1800/ML).

Table 1. Dryland vs Irrigated Chickpea Income vs Row Spacing ($/ha)

Row Spacing	25cm	50cm	75cm	100cm
Irrigated	$2,744	$2,792	$2,544	$1,864
Dryland	$1,088	$1,120	$1,064	$848

In the irrigated treatments the 25 cm and 50 cm spacings both outperformed 75 cm by over $200/ha and 1 m by approximately $900/ha (Table 1). Dryland treatments returned similar results at 25, 50 and 75 cm, with each of these spacings outperforming 1 m by over $200/ha. Whilst there did not appear to be any significant yield benefit to sowing at 25 cm, there was also no significant yield penalty.

Effect of plant population on yield

The plant population effects were not significant and there was no plant population x row spacing interaction in the irrigated or dryland trials.

Implications for growers

- Narrow row spacings (25/50 cm) consistently yield higher than wider row spacings (75 cm and above) for chickpeas.
- Row spacing has a larger effect than plant population on yield.
- While high dry matter production is beneficial in terms of nitrogen contribution, it will be important to investigate factors governing partitioning of dry matter to grain yield under irrigated situations in the future.

Acknowledgements

Many thanks must go to the trial co-operators and the Grains Research and Development Corporation, the Queensland Alliance for Agricultural and Food Innovation and the Department of Agriculture and Fisheries for funding the project.

Trial details

Location:	Goondiwindi
Crop:	Chickpea cultivar PBA HatTrick⊕
Soil type:	Black cracking clay
In-crop rainfall:	approximately 219 mm
Fertiliser & pests were managed as part of the wider paddock.	

Chickpea time of sowing - Emerald

Doug Sands and James Hagan
Department of Agriculture and Fisheries

Research Question: *How does the time of sowing influence the performance of Chickpeas within a range of row spacing and planting densities?*

Key findings

1. Chickpeas planted in April tend to have the highest dry matter production but the lowest harvest index
2. Grain yield production is more efficient in crops planted later in the window
3. Chickpeas have the ability to compensate adequately for changing plant populations
4. Row spacing does influence dry matter production but this does not transfer into grain yield

Background

This time of sowing trial was instigated as part of the Queensland Pulse Agronomy Initiative aimed at increasing the reliability and yield of summer and winter pulses. The time of sowing trials are particularly useful in examining the interaction between management and environment (MxE) for a particular crop. Each sowing time experiences a slightly different set of weather conditions and with intensive monitoring of these crops, the data collected can ascertain the impact of weather on plant physiology. By also changing the position of plants spatially via different row spacing and population, within a changing set of weather conditions, will add more to our understanding of the plants physiology. This trial was based on a site at the Department of Agriculture and Fisheries research facility in Emerald.

Treatments

This trial was a split-split-plot with time of sowing (TOS) randomised at the main plot level, row spacing randomised at the sub-plot level and population randomised at the sub-sub plot level. The three time of sowing blocks were randomised within each replicate, with three replicates spread across the site. Each time of sowing was split into four different row spacing blocks, with each one of these split into four different populations. Table 1 describes the different treatments.

Table 1. Treatments used in this trial

Time of sowing	Row spacing (cm)	Population (plants/m²)
27 April	25	10
2 June	50	20
6 July	75	30
6 July	100	40

The variety Kyabra$^{\Phi}$ was used across the whole trial with all treatments receiving 30 kg/ha of Starter Z at planting.

Starting moisture for the trial site was less than ideal at the first time of sowing with just 55 mm plant available water (PAW) to a depth of 120 cm. Starting nitrogen levels were relatively high with 155 kg N/ha to a depth of 120 cm. As a result of the relatively dry season subsequent irrigations were used to supplement existing soil moisture levels and ensure no bias with regards to soil moisture effect on TOS.

Results

Table 2 summarises some of the key physiological growth data for the 2015 TOS trial, including a comparison with the 2014 TOS trial. The comparison allows some key patterns to be established. For example the April sowing date always has a larger day degree accumulation than the later planting dates despite there not being large differences in flowering periods. Also worth noting is the declining days to maturity and day degree accumulation as the time of sowing gets later in the planting window.

Table 2. Key physiological growth data

Time of Sowing	Days to first flower	Growing Day Degrees to First Flower	Days to Maturity	Growing Day Degrees to Maturity	Calculated PAW (incl. irrigation) mm
April (22/4/14)	67	1343	127	2303	241
June (2/6/14)	59	1005	121	2157	252
July (3/7/14)	60	1014	110	2085	237
April (27/4/15)	62	1140	143	2519	207
June (2/6/15)	58	967	126	2249	225
July (6/7/15)	59	986	100	1840	223

The grain and dry matter (DM) results from the 2015 trial (Figure 1) show some interesting differences between the different sowing dates. While DM production was similar across the April and June planting dates, grain yield differed by 400 kg/ha (21% improvement, Fpr = 0.014). Further to this the July planting date produced almost the same grain yield but with 800 kg/ha less DM (16% less DM, Fpr = 0.026). This means the Harvest Index (HI) for both June and July plantings are significantly superior to the earlier April planting date as can be seen in Figure 2 (Fpr = 0.03).

The HI data for the previous trial grown in 2014 was also a very similar pattern with the later planting dates (June and July) approaching an index of 0.5. This data would indicate that the early sown crops are wasting energy and soil moisture on growing excess DM that is not contributing to grain yield.

When the data is broken down further into row spacing and population categories within each planting date, there appears to be a row spacing interaction but no significant differences for population.

Averaged out over all the planting dates; row spacing had significant differences in DM production with the 25 cm being the highest and 100 cm rows being the lowest , which is a pattern that can be seen in Figure 3 and Table 3.

The differences in dry matter did not translate into difference in yields. Across the June and July planting dates grain yield was remarkably consistent across all row spacings. The earliest

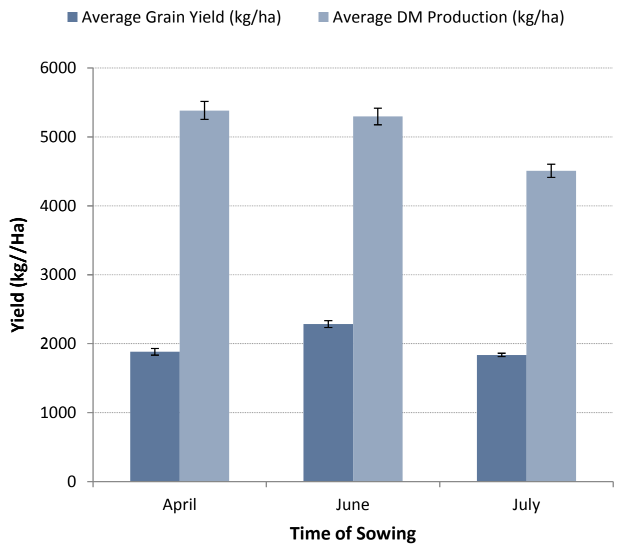


Figure 1. Grain and dry matter yield

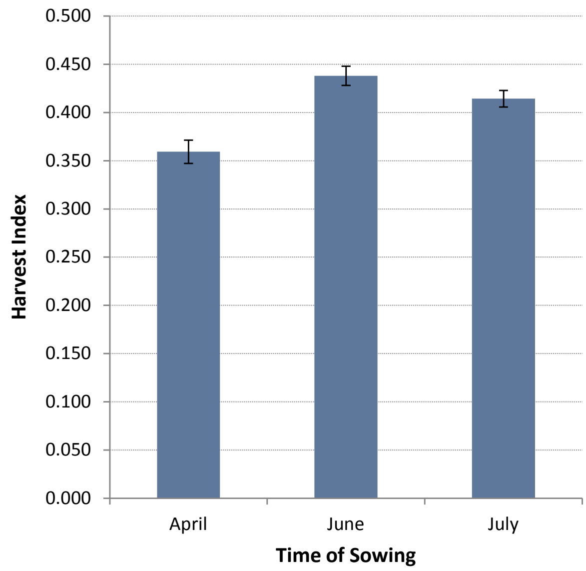


Figure 2. Harvest Index

Table 3. Dry matter production at different row spacings. Letters indicate significant differences. Values with like letters are not different

Row spacing (cm)	100	50	75	25
Mean (kg/ha)	4442	5057	5083	5683
lsd (P=0.05)	a	b	b	c

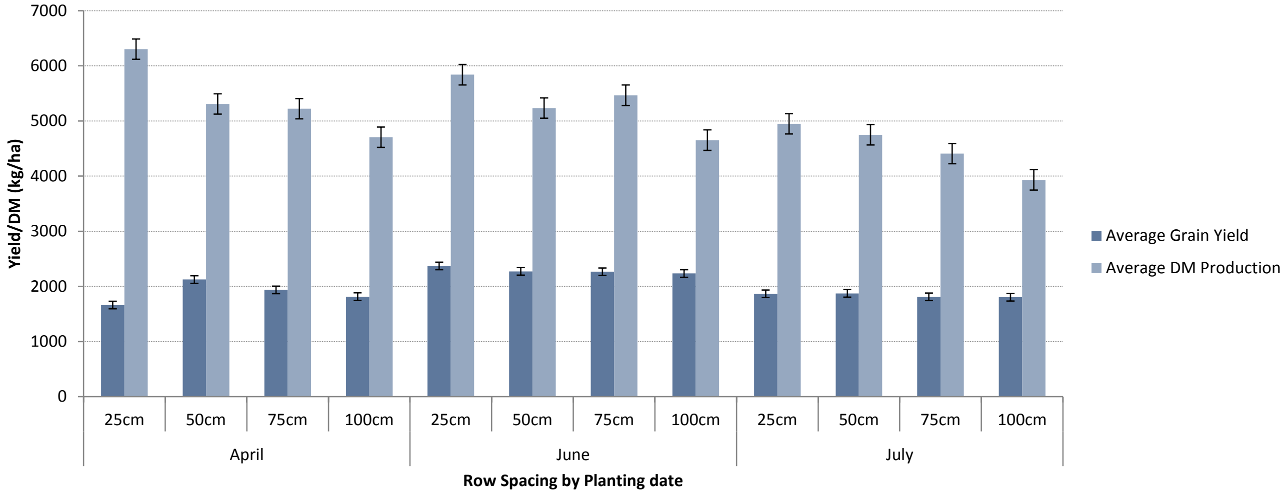


Figure 3. Grain and dry matter yields at different planting times and row spacings

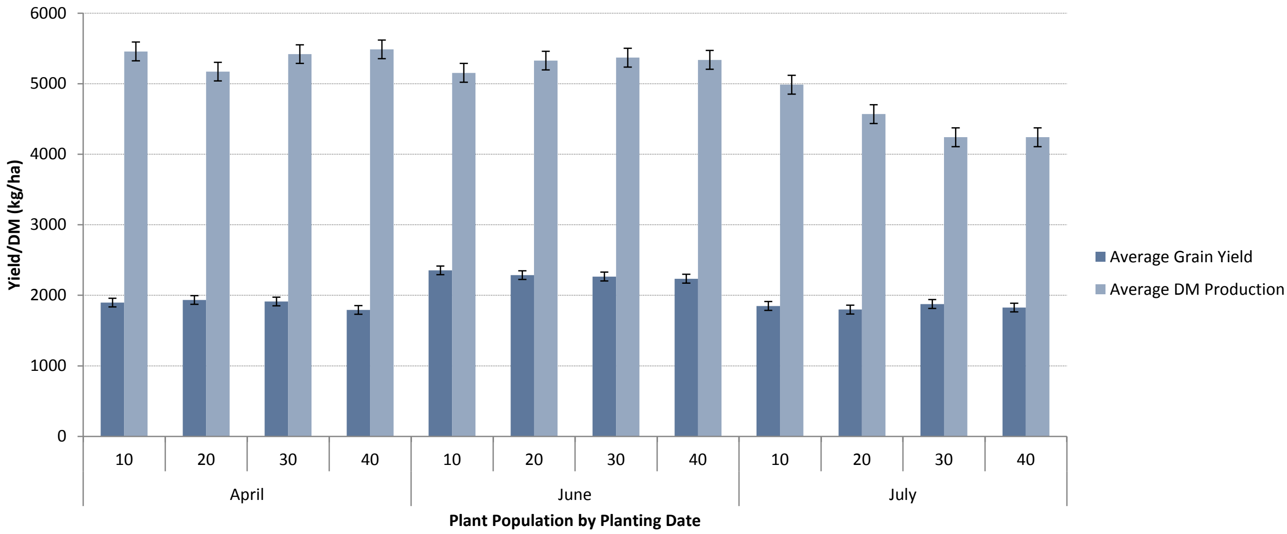


Figure 4. Grain and dry matter yields at different planting times and populations

planting date did have some significant differences with the 50 and 75 cm spacings significantly out yielding the 25 and 100 cm spacings within the early planting date (lsd P=0.05).

Overall, there was no significant difference between populations in either dry matter or grain yield averaged across the whole trial. There was some interaction with plant population and the late planting date with dry matter decreasing as population was increased (Figure 4). Once again this difference did not transfer into grain yield in the latest planting date nor was there any significant difference between populations in any of the other planting dates.

Across planting dates there was a significant response for harvest index to row spacing treatments (Fpr = 0.03). This compliments the

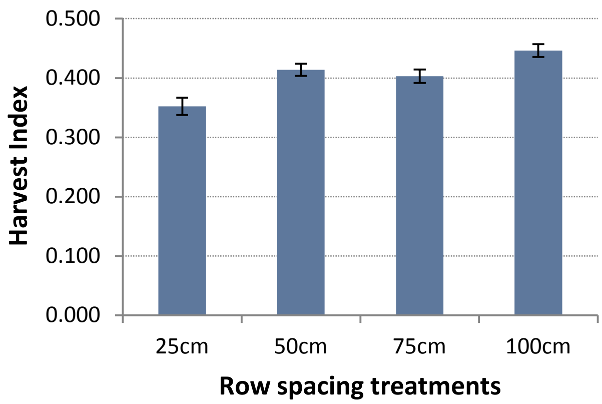


Figure 5. Average Harvest Index

data in Figure 3 showing increasing dry matter production for narrow rows but no increase in yield. Harvest index is therefore increased as row spacing widens (Figure 5). There was no real advantage in population treatments across the different planting dates for harvest index which means that the plant can compensate more easily for changing populations than it can for different spacings across different planting dates.

Another piece of useful data from the time of sowing trial is the leaf area index that was measured just after first flower (5 days April and June, 15 days July). A ceptometer was used to measure light interception underneath the canopy. Although light interception is a notoriously imprecise comparative measurement, the total difference in the data between April and June planting dates is quite large and is an indicator that the vegetative development of the plant prior to flowering is much further advanced in the April planting date than it is in June and July. For the narrow row spacing canopy closure is almost fully achieved by first flower (90% plus) where as in June it is less than 70%.

The information contained in Figure 6 would indicate that despite this difference in canopy early in the flowering period by the time the plants reach maturity, DM was almost the same but yield was significantly different. This means that the June planting created at least 30% of its total dry matter and 20% more yield than the April date during its reproduction phase from almost the same amount of soil water (207 mm versus 225 mm, Table 2).

Basic chickpea physiology requires the vegetative branch to grow and extend to create another node from which an axillary bud can create another flower terminal. The longer the branch, potentially, the more flower terminals can be set. The earlier that the first flower node can occur on that branch, the more potential the branch has to set a higher number of flowers. This may explain why the later planting dates are more efficient in the proportion of dry matter to grain ratios that they seem to develop. A shorter branch at flowering may be an advantage to the plant as it can then set its first flower at an earlier node on the branch stem.

Table 4. Seed counts

Sowing Time X Row spacing treatments	Average Seed No./ plant	Average Seed wt. (g)	Average Seeds/pod
April avg.	**60.56**	**0.21**	**1.27**
25 cm	60.85	0.20	1.30
50 cm	58.55	0.20	1.27
75 cm	70.17	0.20	1.23
100 cm	52.68	0.23	1.29
June avg.	**62.90**	**0.24**	**1.31**
25 cm	41.40	0.25	1.29
50 cm	66.57	0.22	1.29
75 cm	76.73	0.25	1.30
100 cm	66.87	0.24	1.33
July avg.	**80.93**	**0.19**	**1.50**
25 cm	74.92	0.20	1.50
50 cm	82.49	0.19	1.49
75 cm	81.08	0.19	1.49
100 cm	85.21	0.20	1.53

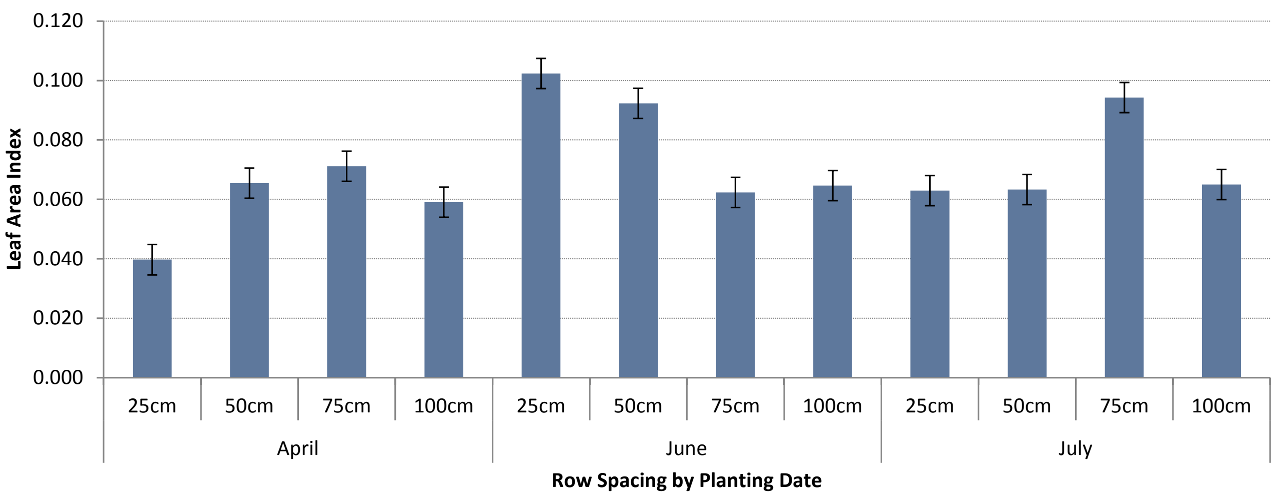


Figure 6. Average Leaf Area Index @ early flower

The data contained in Table 4 comes from plant mapping recordings that were taken just prior to harvest across selected plots. This information would suggest that the yield advantage in the June planting was obtained from a mix of more seeds per pod (leading to more seeds per plant) and a higher grain weight. One explanation for this could be that the later planting dates had the ability to put more of their resources (stored moisture and nutrients) towards setting and filling grain whereas the April planting date had already committed significant resources to dry matter production prior to flowering.

Implications for growers

The data from this trial and the 2014 trial would suggest that the current optimum window for planting chickpeas provides a significant yield benefit over early and late sown crops. However as growers in CQ will continued to be forced to take advantage of planting opportunities as they arise, due to the highly unreliable pattern of winter rainfall in the sub tropics, it is worth investigating whether early sown crops which produce significantly more biomass can be manipulated to turn more of that production into yield. Deep planting strategies have given growers the ability to utilise stored soil moisture from summer dominant rainfall for chickpea production, however this is dependent on getting the crop in the ground sooner rather than later before the moisture dries away from the surface too far; if planting rainfall is non-existent.

If it was possible to achieve a similar harvest index with April sown crops as those achieved in June, at 2015-16 prices, CQ chickpea growers would be over $300/ha better off from any early sown crops, and provide growers with much greater confidence to take advantage of early sowing opportunities into the future.

If 25 cm rows, which also produce significantly more biomass than their wider counterparts, could also be manipulated to conserve more moisture for grain fill, the combined benefit to CQ growers, of early sowing opportunities and narrow row spacing could approach $1000/ha, suggesting there is great value in identifying methods of manipulating plant canopy to reduce dry matter production pre-flower in the early planting dates so that more soil water reserves can be used for setting grain. The data from the time of sowing trials is important in being able to understand the plants growth characteristics. Further work needs to be done to confirm the patterns that have been seen to date but also to test different mechanisms of inhibiting dry matter production in the vegetative growth stages.


April sowing


June sowing


July sowing (centre); June (left) and April (right)

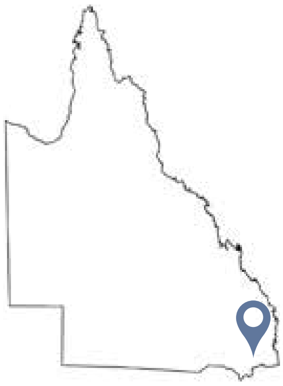
Acknowledgements

The Queensland Pulse Agronomy Initiative (UQ00067) is funded by the Grains Research and Development Corporation, the Queensland Alliance for Agricultural and Food Innovation and the Department of Agriculture and Fisheries.

Trial details

Location:	Emerald Agricultural College Farm
Crop:	Chickpeas 2015
Soil type:	Black/Grey cracking vertosol
In-crop rainfall:	42 mm
Fertiliser:	Starter Z at planting (30kg/ha)

Chickpea time of sowing impact on yield and dry matter production - Warwick



Rebecca Raymond and Kerry McKenzie
Department of Agriculture and Fisheries

Research Question: *What effect does varying time of sowing have on chickpea dry matter production and yield?*

Key findings

1. Time of sowing can increase yield
2. Time of sowing can decrease drymatter production
3. Further research is required to investigate harvest index and partitioning in chickpea

Background

Chickpea (*Cicer arietinum*) is the most adapted winter pulse crop in Queensland with the area expanding to historically high levels in 2010. Seasonal yields of chickpea ranged from 0.5 t/ha to 2 t/ha depending on the timing and severity of biotic and abiotic stresses during the growing season. Although yields as high as 2.5 t/ha have been achieved in varietal evaluation trials, the average yield during the 2008–2011 was approximately 1.2 t/ha.

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.

Treatments

2015 was the first year of trials at the Hermitage Research Station (HRS) site however the third year of chickpea trials, as part of the Queensland Pulse Agronomy Initiative; Winter 2015 was the first Time of Sowing (TOS) trial which included three sowing dates at varied planting densities (10, 20, 30 & 40 plants/m^2) all planted on 0.75 m row spacing with two cultivars (PBA HatTrick[D] and pre-release variety CICA0912).

It was anticipated that the TOS dates would be three weeks apart at each location, the planting dates were 20 May, 12 June and 3 July.

Results

TOS did not have a significant effect on yield at HRS in 2015. There was however significant differences in drymatter production across the sowing dates.

The 2015 season saw crops at this site and three other locations initially grow a large amount of vegetation on available moisture, particularly TOS 1. It cannot be determined from this trial the reason that TOS 2 & 3 did not follow the same pattern. As can be seen in Figure 1 as sowing date moves from May to July drymatter production has reduced, this did not lead to a subsequent loss of yield. The resulting harvest index (HI) has increased for TOS 2 & 3 (Figure 2).

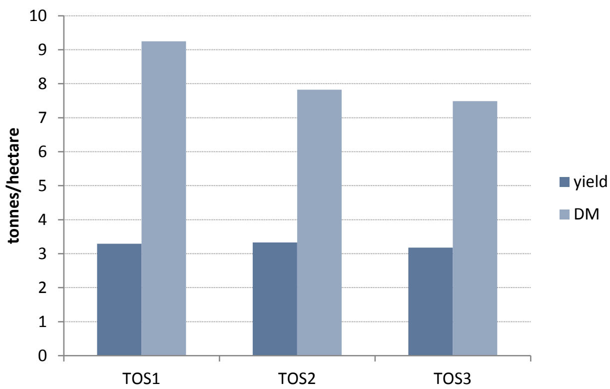


Figure 1. The effect of time of sowing on yield and drymatter (t/ha)

The increase in total drymatter production from TOS 1 (almost 2 t more) would suggest a higher yield potential than later TOSs. Whilst this potential was not reached in the trials with minimal differences in yield across treatments it is worth investigating whether it is possible to manipulate plant growth to convert some of that dry matter production to yield and achieve harvest indexes more closely aligned with later

TOSs. A harvest index of 0.44 in TOS 1 would equate to approximately 900 kg/ha in additional yield, which at $800/t chickpea prices would mean almost $750/ha in additional profit.

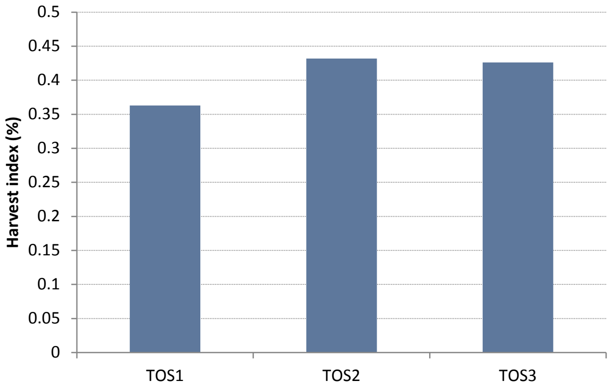
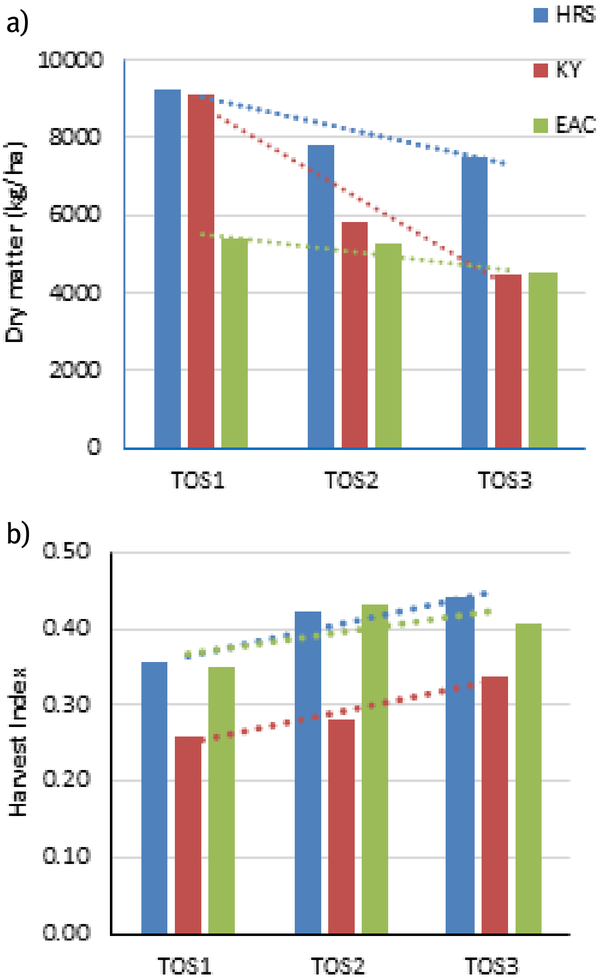


Figure 2. The effect of time of sowing on harvest index, shown as a percentage of drymatter that is converted into yield

A cross site analysis which included this trial and sites at Emerald and Kingaroy was conducted using PBA HatTrick⊕ as the common variety.

All sites had similar trends of earlier sowings achieving higher biomass and lower HI as sowing date was extended (Figure 3).



The factors underpinning the low HI in early planting is not clear. It could be temperature, photoperiod, water or combination of all. If HI could be increased to 0.5 it will result in significant yield increases in early planting. Future research needs to address this problem.

Implications for growers

At this site in 2015, time of sowing had no effect on yield however we found this was not the case at two other trial sites where earlier planted crops achieved higher yields. Earlier planting within the commercial window is best to maximise yields, however later plantings are, after one year of trials, producing lower biomass and as a result, higher harvest index. More investigation is required to better understand the partitioning of chickpea.

Acknowledgements

Many thanks must go to the Grains Research and Development Corporation, the Queensland Alliance for Agricultural and Food Innovation and the Department of Agriculture and Fisheries for the funding support of the project.

Trial details

Location:	Hermitage Research Station (Warwick)
Crop:	Chickpea cultivars PBA HatTrick⊕ and pre-release CICA0912
Soil type:	HRS - black cracking clay
In-crop rainfall:	198 mm (83 mm in the 20 days prior to harvest)
Fertiliser & pests were managed on an as required basis at HRS	

Chickpea time of sowing trial 2015

Figure 3. Effects of time of sowing (TOS) on dry matter production (a) and harvest index (b) PBA HatTrick⊕ grown at Hermitage (HRS), Kingaroy (KY) and Emerald Ag College farm (EAC). TOS 1 late April-mid May; TOS 2 early to mid June; TOS 3 early to mid July.

Faba bean effect of time of sowing on yield and dry matter production - Southern Queensland

Rebecca Raymond and Kerry McKenzie
Department of Agriculture and Fisheries

Research Question: *What effect does varying time of sowing have on faba bean dry matter production and yield?*

Key findings

1. Time of sowing can increase yield
2. Time of sowing can decrease drymatter production
3. Further research is required to investigate harvest index and partitioning in faba bean

Background

Faba bean (*Vicia faba)* is gaining popularity in the northern grains region thanks to higher prices in recent seasons and improved varieties. Southern regions dominate the production for Australia, however Northern New South Wales and Southern Queensland are looking more favourably upon faba bean as part of their rotation. It is an excellent break crop for disease and for its nitrogen fixing ability. Faba bean yields range from 2-4 t/ha, however the pulse agronomy trials have shown a potential of up to 5.5 t/ha. Traditionally faba beans are planted around mid to late April however more and more growers are looking to plant crops earlier to produce larger crops with higher yields. If moisture is received throughout the season this can result in a larger yield however crops not having adequate moisture at the end of the season can lead to lower than expected yields and an inability to fill grain.

Treatments

The 2015 winter was the first year for faba bean time of sowing (TOS) trials as part of the Queensland Pulse Agronomy Initiative. Two trials were planted at Hermitage Research Station (HRS) and Warra. Treatments included were three TOS, two cultivars – PBA Warda$^{\Phi}$ and X220-D (now released as PBA Nasma$^{\Phi}$) and four populations (5, 10, 20, 30 plants/m^2). The row spacing remained on 75 cm for all treatments. It was anticipated that the TOS dates would be three weeks apart at each location however weather prevented this from happening in all cases. The dates used for the trial at each location can be seen in Table 1.

Table 1. Sowing dates at Warra and Hermitage Research Station (HRS)

HRS 1	17/04/2015	Warra 1	9/04/2015
HRS 2	20/05/2015	Warra 2	28/04/2015
HRS 3	12/06/2015	Warra 3	21/05/2015

Results

Time of sowing effects on yield

At HRS there was no statistical difference between the yields between the first and second time of sowing however there was a significant drop in yield of 300 kg from TOS 1 and 500 kg from TOS 2 out to the third sowing date (Table 2).

A similar result was found at Warra, the first two sowing dates showed no significant difference as did the difference between the second and third dates however a marked drop in yield was found between the first and third dates (Figure 1).

Table 2. Effect of time of sowing on yield, Warra (lsd 0.5) & Hermitage Research Station (HRS) (lsd 0.36) 2015. Letters indicate significant differences. Values with like letters are not different.

	TOS 1	TOS 2	TOS 3
Warra	3.56a	3.31ab	2.84b
HRS	3.6a	3.8a	3.3b

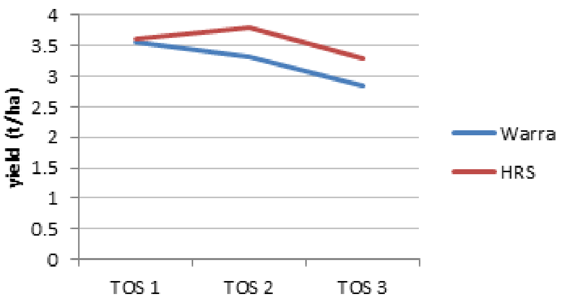


Figure 1. Effect of time of sowing on yield at Hermitage Research Station (HRS) and Warra, 2015

Effect of time of sowing on dry matter

Results indicate that total dry matter declines post the first TOS at both locations; the 2015 season saw crops initially grow a large amount of vegetation on available moisture however we cannot determine from this trial the reason that TOS 2 & 3 did not follow the same pattern (Figure 2). The harvest index has increased for TOS 2 & 3 at both locations however yield is lower (Figure 3). More investigation is needed into crop growth of faba beans to enable us to better understand the crop partitioning and in turn increase yield and harvest index rather than growing large biomass and not being able to convert to yield.

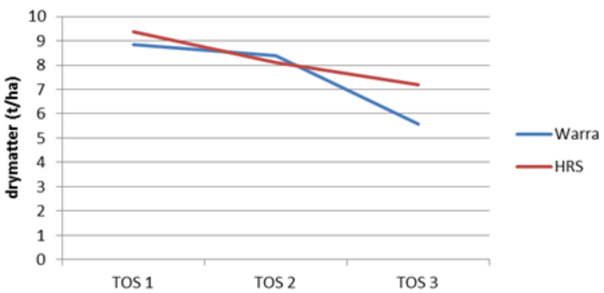


Figure 2. Effect of time of sowing on total drymatter at Hermitage Research Station (HRS) & Warra, 2015

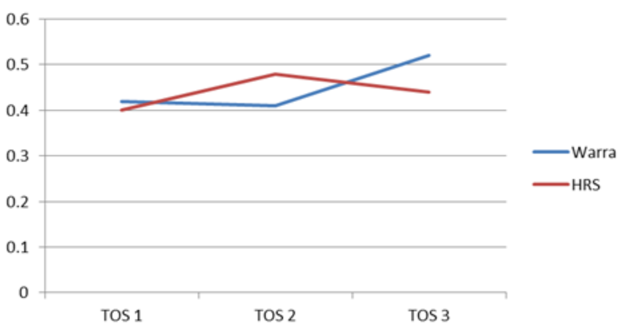


Figure 3. Effect of time of sowing on harvest index, Hermitage Research Station (HRS) & Warra, 2015

(LSD Warra – 0.08, HRS – 0.048)

Time of sowing effects and population on yield

At HRS there was no significant effects on dry matter and yield due to population. There was a trend for improved yields when planting late by planting at higher rates. A similar effect was reported from the Warra site.

Implications for growers

Time of sowing has an effect on both yield and dry matter production. Earlier planting of faba beans is best to maximise yields, later plantings (after one year of trials) are producing lower biomass and as a result, higher harvest index. More investigation is required to better understand the partitioning of faba bean.

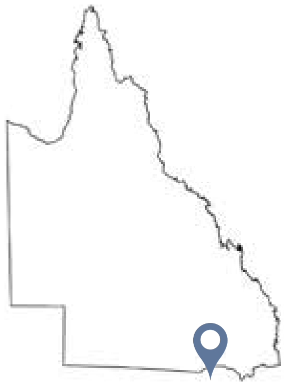
Plant population had less of an effect; continue to plant at recommended rates for your area.

Acknowledgements

Many thanks must go to the co-operators at Warra, and the Grains Research and Development Corporation, the Queensland Alliance for Agricultural and Food Innovation and the Department of Agriculture and Fisheries, for the funding support of the project.

Trial details

Location:	Hermitage Research Station (Warwick) and Warra
Crop:	Faba bean cultivars PBA Warda[⊕] and PBA Nasma[⊕] (previously X220-D)
Soil type:	HRS - black cracking clay & Warra – grey vertosol
In-crop rainfall:	NA
Fertiliser & pests were managed on an as required basis at Hermitage Research Station and as part of the grower's management strategy at Warra.	



Faba bean variety x row spacing x population - Garah

Rebecca Raymond
Department of Agriculture and Fisheries

Research Question: *Do changes in row spacing and plant population affect yield in faba bean?*

Key findings

1. Changes in row spacing can affect yield in faba bean
2. Row spacing has a larger effect on yield than plant density
3. Further research is required to investigate harvest index and partitioning in faba bean

Background

Faba bean (*Vicia faba*) is gaining popularity in the northern grains region thanks to higher prices in recent seasons and improved varieties. Southern regions dominate the production for Australia, however Northern New South Wales and Southern Queensland are looking more favourably upon faba bean as part of their rotation. It is an excellent break crop for disease and for its nitrogen fixing ability. Yield of faba beans ranges from 2-4 t/ha, however the pulse agronomy trials have shown a potential of up to 5.5 t/ha.

Treatments

There have been two seasons of faba bean trials at the Garah site as part of the Queensland Pulse Agronomy Initiative. 2014 saw the planting of three cultivars (PBA Warda$^{\phi}$, PBA Nasma$^{\phi}$ and Cairo) on one planting density of 25 plants/m^2 and on varying row spacings (25, 50, 75, 100 cm).

Winter 2015 saw the inclusion of varied planting densities (5, 10, 20, 30 plants/m^2) across the same four row spacings (25, 50, 75, 100 cm) looking at two cultivars PBA Warda$^{\phi}$ and PBA Nasma$^{\phi}$.

Results

Row spacing effects on yield

Overall, average yields were obtained at the Garah site and significant effects of agronomic treatments were obtained. There was no significant difference overall between the cultivars PBA Warda$^{\phi}$ and PBA Nasma$^{\phi}$ (Table 1). These results are consistent with those found in 2014 at the same site.

Table 1. Effect of cultivar on yield, Garah 2015 (LSD = 0.321). Letters indicate significant differences. Values with like letters are not different

Cultivar	Grain yield (t/ha)
PBA Warda$^{\phi}$	2.97a
PBA Nasma$^{\phi}$	3.24a

The 2014 season saw significant effects of the agronomic treatments observed with varieties responding positively to decreasing row spacing.

The narrower row spacings of 25 cm and 50 cm have significantly out yielded the wider spacings of 75 cm and 100 cm in both 2014 and 2015.

Overall, in both years that row spacing and yield have been investigated at Garah, significant effects of the agronomic treatments were observed with both varieties responding positively to decreasing row spacing shown in Figure 1.

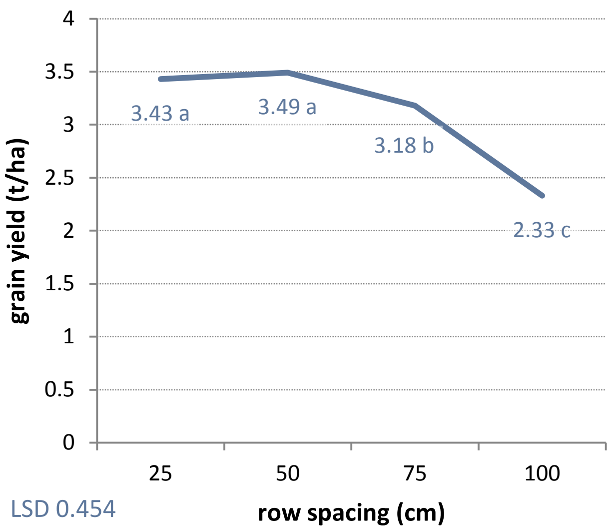


Figure 1. Effect of row spacing on yield, Garah 2015. Letters indicate significant differences. Values with like letters are not different

Table 2. Relative annual benefit of row spacings

	0.25m row spacing	0.5m row spacing	0.75m row spacing	1m row spacing
Income ($/ha)	$1,372	$1,396	$1,272	$932
Benefit vs 1m ($/ha)	$440	$464	$340	-

At a faba bean price of $400/t the annual benefit from sowing at 25 or 50 cm compared to 100cm spacings is approximately $450/ha. As the cost of additional tynes in the ground is unlikely to exceed $5/ha, it is reasonable to consider this additional income as profit (Table 2).

Effect of plant population on yield

In 2015, population effect on yield was investigated, however no significant differences were found between the 5, 10, 20 and 30 plants/m^2. It is thought that this is due to the crop having a tough finish and running out of soil moisture at grain fill. Assessing total dry matter (t/ha) in the same crop, 5 plants/m^2 was significantly lower than the 10, 20 and 30 plants/m^2 treatments (Figure 2). Further analysis of water use needs to be completed, however with no/very little rainfall after August it could be suggested that the crop ran out of moisture at grain fill and the plots with higher populations had less moisture available to finish (see photograph below). As a result, the yield was not significantly higher as expected at the higher planting density.

The crop at physiological maturity

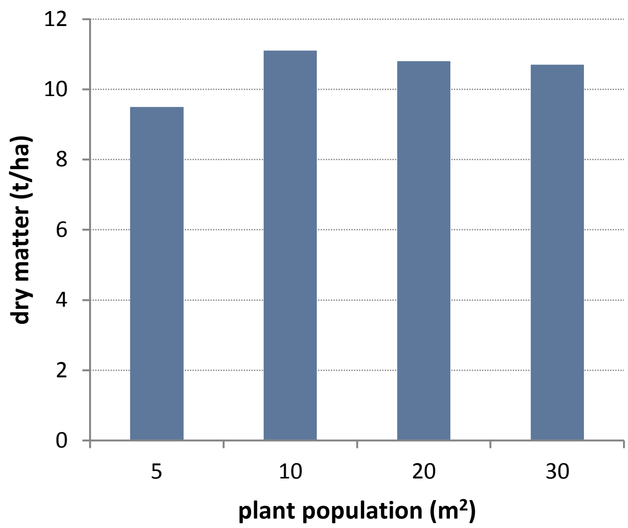


Figure 2. Effect of population on dry matter (t/ha)

Implications for growers

Narrow row spacing (25/50 cm) consistently yielded higher than wider row spacings, (75 cm and above) for faba beans.

This effect has been seen across two years and differing seasons and environments.

Row spacing has a larger effect than plant population on yield.

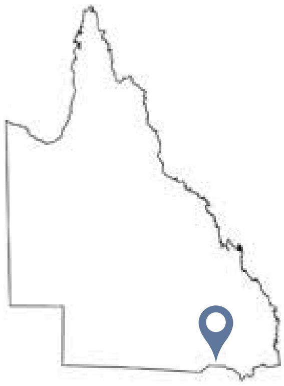
Acknowledgements

Many thanks must go to the trial co-operators for hosting the trial, and the Grains Research and Development Corporation, the Queensland Alliance for Agricultural and Food Innovation and the Department of Agriculture and Fisheries, for the funding support of the project.

Trial details

Location:	Garah
Crop:	Faba bean cultivars PBA Warda$^{\Phi}$ and PBA Nasma$^{\Phi}$
Soil type:	Black cracking clay
In-crop rainfall:	266 mm
Fertiliser & pests were managed as part of the wider paddock.	

Chickpea effect of late season supplementary irrigation - Goondiwindi



Grant Cutler
Department of Agriculture and Fisheries

Research Question: *To what extent do varied amounts of late season irrigation have on the yield and components of yield in chickpea?*

Key findings

1. Pod formation and seed set was found to increase with increasing irrigation amounts
2. Although yields increased 100 seed weights remained similar
3. Water-use efficiency was found to increase with the availability of more soil moisture

Background

Chickpeas have been a crop widely planted in Southern Queensland. However they can be frequently exposed to periods of terminal drought during pod and seed formation which can limit yields under rainfed situations. Whilst the crop is considered to have some tolerance to drought stress, yields can be increased significantly through the alleviation of terminal drought by using supplementary irrigation during flowering and pod fill.

Supplementary irrigation is often used to either maintain an average yield of a predominantly rainfed crop where rainfall has been insufficient to prevent late season terminal drought, or to obtain the maximum yield possible with the least amount of applied water in a low-water year. The use of supplementary irrigation may not only increase the yield potential of a rainfed crop, but also improve the water-use efficiency (WUE) indices of that crop compared to a fully-irrigated crop.

Treatments

- 45 mm applied irrigation
- 75 mm applied irrigation
- 105 mm applied irrigation

The treatments were implemented by turning off emitters and reducing or increasing nozzle/emitter output by 50% as the centre pivot moved across the trial site. Treatments were applied in three irrigation events with the pivot delivering water across the site twice per event.

Results

As expected, total pod and seed characteristics for the crop improved with the increase in amount of water applied late in the season. Plants within the low water treatment (45 mm) produced almost 50% less pods than the plants in the high (105 mm) water treatment. Figure 2 shows the improvement of average yield per plant in relation to amount of water applied. The same trend can be seen between both Figure 1

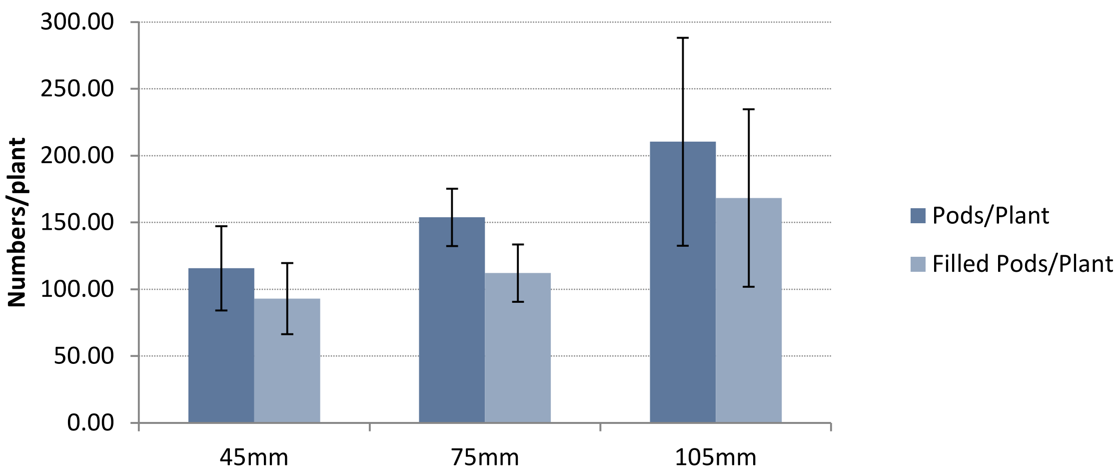


Figure 1. Effect of irrigation treatment on podding characteristics

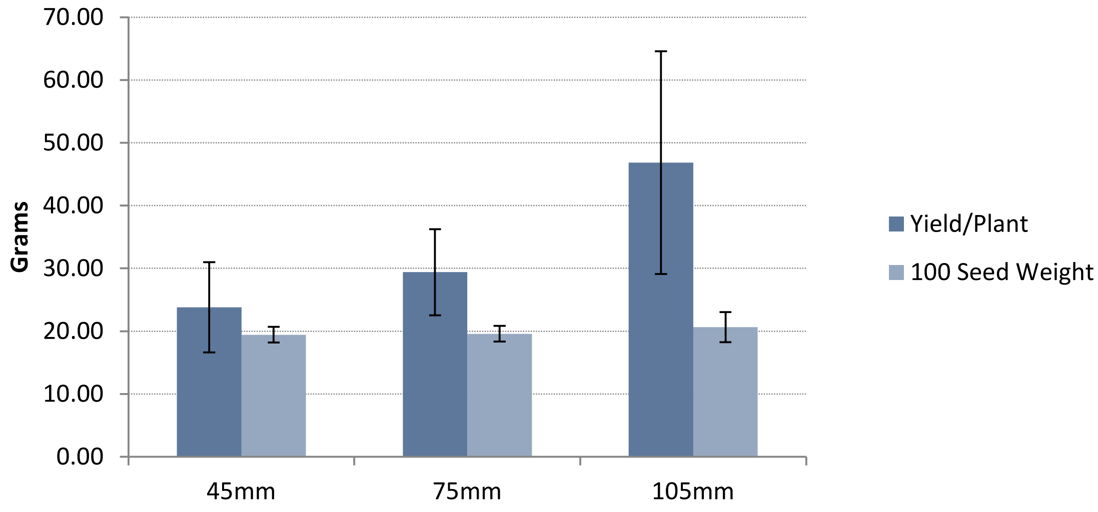


Figure 2. Effect of irrigation treatment on seed characteristics

and Figure 2, showing that an increase in soil moisture late in the season attributes greater to an improved yield. However, although seed yield per plant increased, 100 seed weight did not differ significantly between treatments.

The majority of the improvement can be attributed to the greater soil moisture availability late in the season allowing the plant to produce flowers/pods over a longer period, leading to a higher yield than the plants that had run out of water. This data suggests that late season availability of moisture does not affect seed size (Figure 2), but rather affects the plants ability to set a greater yield.

Implications for growers

This trial suggests that in water limited years there is potential to maintain yields and minimise the effect of terminal drought late in the growing season through supplementary irrigation. The amount required will vary in response to when soil moisture runs out, and the amount of water available or budgeted for. Given the current price, and the response of chickpea to late season irrigation, significant increases in net income per unit of water can be achieved.

Irrigation treatments being applied across trial site, note the low water treatments as show by the darker areas within the crop

Acknowledgements

The irrigation team would like to thank the host of this trial.

This trial was conducted under the 'Improved economic productivity from irrigated agriculture in the Queensland Murray-Darling Basin' project funded by the Australian Government under the Murray-Darling Basin Regional Economic Diversification Program

Trial details

Location:	Goondiwindi, Queensland
Crop:	Chickpea (PBA Boundary ⦹)
Soil type:	Grey vertosol

Nutrition research

Research into grains nutrition is currently focused on phosphorus (P), potassium (K) and sulfur (S). Phosphorus and potassium are immobile elements and so don't move in the soil from where the application zone is. Placing these elements deeper into the soil profile at a depth of 15-20 cm below the soil surface (deep placement) is being evaluated as way to manage nutrient stratification. Under this scenario, the very top layers of soil (0-5 cm) are enriched due to the return of crop stubbles and decomposition depositing these immobile nutrients into this layer.

Initial work in Central Queensland is attempting to resolve the effects of separate or additive applications of nutrients to increase grain yields. Two long-term PKS combination screening sites have been established north and south of Emerald to explore outcomes of individual input of P, K or S as well as the response to combinations of nutrients (e.g. P and K, P and S, etc.). These are allowing identification of the nutrient or nutrients to pursue with application rate experiments.

Examination of soil P at a long-term cropping experiment has however identified that most crop P is being recovered from the soil layer below the surface 10 cm – the 10-30 cm layer. This layer has more root exploration and longer periods of root activity as it is refilled with rainfall during the growing season. Previous research in southern Queensland has confirmed the potential to increase grain yields by applying phosphorus into this layer, but this work was primarily focused on higher application rates to establish "proof of concept" from deep placement. The subsequent research outlined here is aimed at establishing the interaction between starter P application and increasing rates of deep placed P for grain yield over different crops and growing seasons.

Results in terms of crop nutrient recovery and grain yield responses are highlighting differences due to contrasting root architecture of fibrous rooted grass species (i.e. wheat, barley, sorghum, maize) compared to the coarsely rooted pulse crop species (i.e. chickpea, mungbean). Deep placement rate response work has been undertaken using fertiliser placed on 50 cm band distances. How changing this to 25, 50 or 100 cm band spacing alters crop recovery by different species is a new research direction that commenced this season.

Overall, results are encouraging from this winter season's data. Most sites in Central Queensland have demonstrated a yield response to deep placed P and/or K when crop nitrogen supply has not been a limiting factor. Yield effects in southern Queensland with deep placed fertiliser have been more varied, ranging from none in some chickpea crops to a 480 kg/ha increase with wheat at Goondiwindi.

Nutrition trials 2015

The residual value of deep placed phosphorus, potassium and sulfur in scrub soil - Dysart

Doug Sands, Dr David Lester and James Hagan
Department of Agriculture and Fisheries

Research Question: *Does the deep placement of phosphorus (15 to 20 cm), potassium and sulfur have an impact on sorghum yields two years after the original application?*

Key findings

1. Sorghum yields were increased by 15% (445 kg/ha) in the best performing phosphorus treatment in the 2nd year of production
2. Sorghum yields were increased by 9% (313 kg/ha) in the best performing potassium treatment in the 2nd year of production
3. There was no response to sulfur application for the 2nd year of production

Background

There is some soil testing evidence to suggest that nutrient stratification of non-mobile nutrients such as phosphorus (P) and potassium (K) is occurring across a range of Central Queensland (CQ) soil types. Nutrient stratification occurs when there is a redistribution of non-mobile nutrients through several crop cycles. Plants take up nutrients from the lower parts of the profile (10-30 cm) and then they are released through stubble breakdown into the top 10 cm of the profile where they then stay because they are immobile elements. The problem is further enhanced by the application of starter fertilisers also into the top 10 cm of the soil profile.

In CQ conditions grain crops, both summer and winter, rely on stored moisture to fill grain as the top 10-15 cm is too dry for plant roots to be active. Nutrients can only be taken up via soil moisture; consequently most of the plant nutrients are sourced deeper in the profile (below 10-15 cm). If this zone is depleted in non-mobile nutrients then it can significantly limit grain yield.

This research is investigating if the application of P and K in the 10-30 cm zone of the soil profile can replenish this depleted zone enough to improve yield in the presence of other non-limiting nutrients and can this replenishment last for multiple crop cycles.

Treatments

The treatments at this site were established in August of 2013. The first crop on the site was sorghum harvested in June 2014. The site was then fallowed through to sorghum again and planted on 9 January and harvested on 8 May 2015.

Phosphorus trial:

There were eight treatments in total, which included four P rates; 0, 10, 20, and 40 kg P/ha. All of these treatments had background fertiliser applied at the same time to negate any other potentially limiting nutrients. This background fertiliser included; 80 kg of nitrogen (N), 50 kg of K, 20 kg of sulfur (S) and 0.5 kg of zinc (Zn). The other treatments included 0P and 40P without background fertiliser except N and Zn (0P-KS, 40P-KS). The last two treatments were farmer reference (FR) plots, and an extra 0P plot to give us two controls for each replicate. The FR treatments had nothing applied except what the farmer applied in line with normal commercial practice.

These treatments were applied using a fixed tyne implement which delivered the P and K, 20 cm deep and the N and S, 10-15 cm deep. The bands of fertiliser were placed 50 cm apart in plots that were 8 m wide by 32 m long. The bands were placed in the same direction as the old stubble rows. There were six replicates making a total of 48 plots for the trial.

The 2015 crop received 100 kg/ha of urea, applied two months prior to planting and no starter fertiliser at planting. The sorghum variety, MR-Bazley, was planted at 55 000 seeds/ha. The crop received 322 mm of in-crop rainfall of which 93% of this rainfall occurred before flowering.

Potassium trial:

There were eight treatments in total which included four K rates; 0, 25, 50, 100 kg K/ha. All of these treatments had background fertiliser applied at the same time to negate any other potentially limiting nutrients. This background fertiliser included; 80 kg N/ha, 20 kg P/ha, 20 kg S/ha and 0.5 kg Zn/ha. The other treatments included 0K and 100K without any background fertiliser except N and Zn (0K-PS, 100K-PS). The last two treatments were a farmer reference (FR) and an extra 0K to give two controls in each replicate. The FR plots have not been treated with anything except what the farmer applied in line with normal commercial practice.

Applications were done in the same way as the P trial and the other trial details remain the same.

Sulfur trial:

There were eight treatments in total which included four S rates; 0, 10, 20, 30 kg S/ha. All of these treatments had background fertiliser applied at the same time to negate any other potentially limiting nutrients. This background fertiliser included; 80 kg N/ha, 20 kg P/ha, 50 kg K/ha and 0.5 kg Zn/ha.

The other treatments included 0S and 30S without any background fertiliser except N and Zn (0S-PK, 30S-PK). The last two treatments were similar to the other trials with an extra 0S treatment being included as another control and a farmer reference treatment (refer P and K trials).

Results

Total plant dry matter samples were cut on 23 April from all three trials. Only selected treatments were sampled (Table 1). All samples were dried and weighed before being ground and a sub sample sent for total nutrient analysis.

Grain yield was measured by harvesting the middle four rows of each plot with a plot harvester on 8 May. Grain yield was corrected for moisture with all plots brought back to a receival moisture of 12.5%. A sub sample of grain was taken for each plot and ground, with a sub sample sent for total nutrient analysis. Once again only selected grain samples from each trial were analysed (Table 1).

Table 1. List of samples taken from each trial for nutrient analysis

Trial	Treatments sampled for analysis
P trial	0P, 20P, 40P, FR
K trial	0K, 50K, 100K, FR
S trial	0S, 10S, 30S, FR

Phosphorus trial

Table 2 shows a significant difference to the P treatments with the best performing treatment giving a 15% yield improvement over the 0P rate and a 28% improvement over the FR plots. There was also a small reduction in yield when the background K and S was not applied to the maximum rate of P (40P-KS versus 40P). This would indicate that once P requirements have been satisfied then K is also a limitation to grain yield. This is confirmed by the fact that when the background K and S was not applied to the 0 rate of P; yields were only marginally reduced by 2-3%. This could indicate that P is the most limiting nutrient, therefore when it is not present (0P rate) there can be no effect from any additional K.

Table 2. Comparison of average grain yields across all treatments in the phosphorus trial

Treatments	2013-14 Grain Yields (kg/ha)	2014-15 Grain Yield (kg/ha)	2014-15 Relative difference to 0P (kg/ha)	2014-15 Relative difference to 0P (%)
FR	2332	2561 a	-374	-12.7%
0P-KS	2727	2866 a	-69	-2.4%
0P	2795	2935 ab	0	0.0%
10P	3191	3301 bc	366	12.5%
20P	3343	3381 c	445	15.2%
40P	3490	3334 bc	399	13.6%
40P-KS	3196	3232 bc	297	10.1%

Means with the same letter are not significantly different at a 5% level

Over the past two years the cumulative benefit of P treatments assessed compared to typical farmer practice (FR) has ranged from $13 to $216/ha, with all treatments except 0P providing positive returns in the first year following application. Interestingly it appears as though the tillage, background N and Zn, provided significant first year benefits of almost $100/ha, which may assist in offsetting the upfront cost of deep nutrient application compared with their longer term response.

Table 3. Economics of deep phosphorus application after two years of cropping

Treatments	Cost of treatment ($/ha)	2013-14 Benefit ($/ha)	2014-15 Benefit ($/ha)	Current Total Net Benefit	Current ROI
FR	$ -	$ -	$ -	$ -	0.0
0P-KS	$91	$91	$55	$55	0.6
0P	$161	$106	$67	$13	0.1
10P	$168.07	$198	$133	$163	1.0
20P	$175.06	$232	$148	$205	1.2
40P	$189.05	$266	$139	$216	1.1
40P-KS	$118.85	$199	$121	$201	1.7

It is important to note that the costs of treatment include both the application cost of deep ripping ($30/ha), background costs of $131ha (N, $61, K and S where applied, $43 and $27 respectively and Zn $0.01), and variable P costs at $1.46/kg. As P was applied as MAP (22.5% P, 11.2% N), background N was reduced in P treatments so total N was equal to 80 units.

In a typical paddock environment it is likely that the only costs would be application and variable cost of P, as the background treatments N,K,S treatments were applied to ensure that none of these nutrients were plant limiting. A similar logic is applied in K and S trials. Therefore the benefits in Table 3 are likely to be highly conservative, with more realistic net benefits being up to $131/ha higher.

Whilst the treatment which currently has the highest Return on Investment (ROI) is 40P-KS, and second highest being 20P it is likely that this will change as duration of response is better known. 40P is likely to have longer lasting responses as it is currently only $4/ha behind 20P in absolute terms, whilst $16 ahead of 40P-KS. Further monitoring will be required to determine how long the higher P treatments will continue to provide benefits.

Potassium trial

Table 4 shows a significant difference to the K treatments with the most significant being the 50K and 100K rates. The maximum response is less than 10% within the K treatments but when compared to the commercial practice in the FR plots there is nearly a 20% response (640 kg/ha). The other most significant response within the K trial was between the maximum rate of K, with and without background P (100K versus 100K-PS). This would indicate that there is an additive response between the background P and the maximum K treatment (nearly 15%).

Unfortunately this significant response was not repeated for the 0K treatment which would indicate the interaction between P and K is more significant at the higher rates of K application.

Table 4. Comparison of average grain yields across all treatments in the potassium trial

Treatments	2013-14 Grain Yields (kg/ha)	2014-15 Grain Yield (kg/ha)	2014-15 Relative difference to 0P (kg/ha)	2014-15 Relative difference to 0P (%)
FR	2644	2966 a	-330	-10.0%
0K-PS	2930	3083 ab	-212	-6.4%
0K	3230	3295 bc	0	0.0%
25K	3271	3400 cd	105	3.2%
50K	3495	3608 d	313	9.5%
100K	3434	3542 d	247	7.5%
100K-PS	2867	3062 a	-233	-7.1%

Means with the same letter are not significantly different at a 5% level

All treatments aside from 0K-PS and 100K-PS have returned positive benefits when compared with typical farm practice treatments (FR), ranging from $33 to $107/ha (Table 5). It appears that tillage along with N and Zn has had a significant impact, however not enough to offset the cost. Once again the treatment cost includes the application costs of ripping at $30/ha, as well as background nutrition costs of $117/ha ($61 N, where applied P and S of $29 and $27 respectively, Zn $0.01) and a variable K cost of $0.86/kg. The current total net benefit values are thus likely to be very conservative compared to what would occur in a typical field situation.

The 50K treatment currently stands out; however as per the P trial, duration of response will be the key factor in determining which treatment ends up best. If 50K is declining in impact and 100K shows further benefits under continued

Table 5. Economics of deep potassium after two crops

Treatments	Cost of treatment ($/ha)	2013-14 Benefit ($/ha)	2014-15 Benefit ($/ha)	Current Total Net Benefit	Current ROI
FR	$ -	$ -	$ -	$ -	0.0
0K-PS	$91	$66	$21	-$4	0.0
0K	$147	$135	$59	$47	0.3
25K	$169	$144	$78	$53	0.3
50K	$190	$196	$116	$121	0.6
100K	$233.28	$182	$104	$52	0.2
100K-PS	$177	$51	$17	-$108	-0.6

cropping, then these higher rates will quickly increase their return on investment, as well as addition to total profit.

Sulfur trial

The S trial produced very few significant differences. The additional S treatments did not produce any significant responses (Table 6). The biggest significant difference was between the 0S rates, with and without background P and K (0S versus 0S-PK). The background P and K produced an extra 9% yield (304 kg/ha) without any S present. The response was similar at the highest rate of S application with a 10% difference in yield when background P and K were removed from the treatment. Unfortunately the statistical analysis proved this was not significant at the 5% level.

Table 6 reinforces the fact that P and K play the dominant role in grain yield at this site rather than S.

Table 6. Comparison of average grain yields across all treatments in the sulfur trial

Treatments	2013-14 Grain Yields (kg/ha)	2014-15 Grain Yield (kg/ha)	2014-15 Relative difference to 0P (kg/ha)	2014-15 Relative difference to 0P (%)
FR	2808	2817 a	-564	-16.7%
0S-PK	3160	3077 ab	-304	-9.0%
0S	3475	3381 c	0	0.0%
10S	3583	3484 bc	103	3.1%
20S	3345	3391 abc	11	0.3%
30S	3397	3492 abc	112	3.3%
30S-PK	3225	3136 abc	-245	-7.2%

Means with the same letter are not significantly different at a 5% level

Current S treatment results suggest negligible difference between 0 and 30S, whilst all treatments did provide some benefit over standard farm practice (FR), these benefits can largely be attributed to tillage response ($76/ha), and background P and K ($130/ha) (Table 7). It would appear at current yields that S is not a major constraint at this site. Treatment costs are made up of $30/ha application, and background nutrition costs of $133 (N $61, P and K $29 and $43 where applied, and Zn of $0.01) and variable S costs of $1.36/kg, which as per the other treatments means any net benefits are very conservative.

Implications for growers

This site has now grown two sorghum crops on the same trial site from deep placement applications that occurred in August of 2013. In both years there was a significant response to P (22% 1st year and 15% 2nd year) and K (8% year 1 and 9.5% year 2) from the one application. For the P trial alone this represents an accumulated extra yield of just over 1000 kg/ha of sorghum for the best rates of P over two seasons. With the additional nitrogen and ripping this accumulated benefit increases to 1900 kg/ha (comparison to FR treatments).

For the K trial alone the accumulated benefit in yield is only 580 kg/ha (approx. half the P trial) to applied K over the two seasons. With additional nitrogen and ripping this benefit increases to 1490 kg/ha (comparison to FR treatments).

It is worth noting that this site has marginal soil levels for all four macro-nutrients (N,P,K,S – see trial details) however it seems that P and K are the most limiting to yield and therefore the response to N and S on their own has been minimal. It is clear from this set of trials that there is an additive effect by having both P and K applied together and that this then has additional improvement on nitrogen uptake as well.

Table 7. Economics of deep sulfur after two crops

Treatments	Cost of Treatment ($/ha)	2013-14 Benefit ($/ha)	2014-15 Benefit ($/ha)	Current Total Net Benefit	Current ROI
FR	$ -	$ -	$ -	$ -	0.0
0S-PK	$91	$60	$47	$ 16	0.2
0S	$163	$130	$102	$68	0.4
10S	$176.68	$153	$120	$ 97	0.5
20S	$190.28	$132	$103	$45	0.2
30S	$203.88	$155	$122	$73	0.4
30S-PK	$131.68	$73	$57	-$1	0.0

If P and K are depleted to marginal levels based on soil test analysis in the 10-30 cm zone, then it is highly likely that a significant response will be obtained by the banding of both these nutrients within the same 10-30 cm zone. It is also possible to get a response over two successive crops from one application of these nutrients. It is still an unknown how many more successive crops will respond to this initial application and which rate of application will be the most effective.

Acknowledgements

It is greatly appreciated to have the continued support of trial co-operators, by hosting this trial site.

This work is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ00063 'Regional soil testing guidelines for the northern grains region'.

Trial details

Location:	Dysart
Crop:	Sorghum (MR-Bazley)
Soil type:	Grey vertosol (Brigalow scrub) on minor slopes.
Fertiliser:	Urea applied @ 100 kg/ha in November 2014 (0-10 cm). No starter fertiliser applied at planting.
In-crop rainfall:	322 mm

Selected soil fertility characteristics for the trial site

Depth (cm)	Nitrates	Sulphur	Col P	BSES P	Exc. K	ECEC
0-10	2	1.7	5	8	0.25	35.63
10-30	1	1.6	1	3	0.12	28.77

Phosphorus trial prior to pre-harvest spray out. Looking along first block of treatments. Difficult to see visual differences

Potassium trial mid-vegetative stage. Looking along first block of treatments. Difficult to see visual differences

Sorghum production four years after deep phosphorus and potassium application - Gindie

Doug Sands, Dr David Lester and James Hagan
Department of Agriculture and Fisheries

Research Question: *Does the application of immobile nutrients such as phosphorus and potassium continue to improve yields four years after the initial deep placement application?*

Key findings

1. The combination of phosphorus and potassium applied together as a treatment had the largest response in grain yield (16.5%) for sorghum harvested in 2015
2. Potassium applied on its own gave a 10% response and phosphorus on its own gave only a 1-2% response
3. Potassium is the primary limiting nutrient for this trial site but P can have an additive effect when combined

Background

There is some soil testing evidence to suggest that nutrient stratification of non-mobile nutrients such as phosphorus (P) and potassium (K) is occurring across a range of Central Queensland (CQ) soil types. Nutrient stratification occurs when there is a redistribution of non-mobile nutrients through several crop cycles. Plants are taking up nutrients from the lower parts of the profile (10-30 cm) and then being released through stubble breakdown into the top 10 cm of the profile, where they stay because they are immobile elements. The problem is further enhanced by the application of starter fertilisers into the top 10 cm of the soil profile.

In CQ conditions many grain crops, both summer and winter, rely on stored moisture at depth to fill grain, as the top 10-15 cm is too dry for plant roots to be active. Nutrients can only be taken up via soil moisture; consequently the majority of nutrients are coming from deeper in the profile (below 10-15 cm). If this zone is depleted in non-mobile nutrients, grain yield can be limited.

This research is investigating if the application of P and K in the 10-30 cm zone of the soil profile can replenish this depleted zone enough to improve yield (if other nutrients are non-limiting) , and if this can last for multiple crop cycles.

Treatments

The treatments at this site were established in October 2011. The 2015 sorghum crop was the third crop harvested from this trial. Since application of the treatments; crops planted include sorghum (2012), chickpeas (2013) and finally sorghum (2015). Each crop had starter fertiliser applied in the top 10 cm at planting and the sorghum crops also had additional nitrogen applied (110–120 kg/ha of urea).

There were eight treatments applied across six replicates (Table 1).

Table 1. Treatment description

		Nutrient applied (kg/ha)									
Trt No.	Treatment name	N	P	K	S	B	Cu	Fe	Mn	Mo	Zn
1	Control	100	-	-	-	0.8	0.8	2.2	1.8	0.04	2.5
2	P	100	40	-	-	0.8	0.8	2.2	1.8	0.04	2.5
3	K	100	-	200	-	0.8	0.8	2.2	1.8	0.04	2.5
4	S	100	-	-	40	0.8	0.8	2.2	1.8	0.04	2.5
5	P:K	100	40	200	-	0.8	0.8	2.2	1.8	0.04	2.5
6	P:S	100	40	-	40	0.8	0.8	2.2	1.8	0.04	2.5
7	K:S	100	-	200	40	0.8	0.8	2.2	1.8	0.04	2.5
8	P:K:S	100	40	200	40	0.8	0.8	2.2	1.8	0.04	2.5

Note: Nitrogen (N), Phosphorus (P), Potassium (K), Sulfur (S), Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Zinc (Zn)

Three control plots were used in each replicate to give a more realistic estimate of the average performance of the untreated plots, and also to assist with any subsequent analyses of spatial variability in the analysis of treatment effects. The trial had 12 plots per replicate and 72 plots for the whole trial. The treatment rates (Table 1) were split between a shallow (10 cm) and a deep (20 cm) application. The fertiliser bands were placed 40 cm apart with a fixed tine implement. The plots were 32 m long by 8 m wide and were split either side of the planter tram tracks which were 12 m apart from centre to centre. All crops were planted and sprayed by the grower co-operator as part of their normal management regime.

The 2015 sorghum crop had an additional 110 kg urea applied prior to planting along with 20 kg/ha of a starter blend based on CK55S. MR-Buster⁽ᴰ⁾ was planted at 60,000 seeds/ha on 1 m rows on 23 December 2015 and harvested on 1 April 2015. The crop received a total of 244 mm of rainfall with 90% of this falling before flowering.

Total biomass samples were cut at maximum dry matter accumulation or when the grain was at the soft dough stage. These samples were dried, weighed and selected samples were ground for nutrient analysis. Grain yields were measured by harvesting two strips out of each plot with a plot harvester. After harvest, weights were measured then selected grain samples were taken and ground for analysis. Grain yields were adjusted for moisture to a standard of 12.5%.

Results

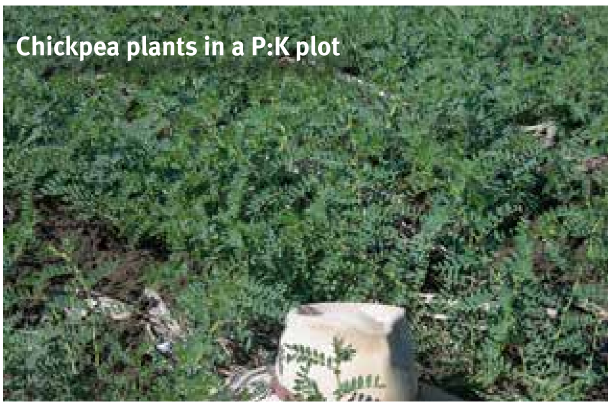
Grain yield data for the 2015 sorghum crop is contained in Table 2 along with the historical data from the previous two crops.

Table 2 shows a contrast in treatment results across the years. In the 2012 sorghum crop, the main response was to P as any treatment including P showed a significant difference to the control. The 2013 chickpea crop gave a significant response to K. This is demonstrated by the fact that P and S on their own gave no significant response but K did. Any other treatment with K present in the mix (PK, KS and PKS) also gave a significant response. This K response was also repeated in the following sorghum crop in 2015. This was surprising given that the first sorghum crop did not produce a response to K. Results suggest that in both crops where K gave a significant result, the addition of P had an additive effect to produce an even larger response. In both 2013 and 2015 the PK combination produced the best yield.

Figure 1 and Figure 2 illustrates this same yield data in a different way. Figure 1 shows the difference in grain yield in kg/ha in comparison to the control plots in the same year. Figure 2 shows the same yield data as Figure 1 but presented as a percent difference compared to the control plots.

These figures show a large response to P in the first crop (dark green) and then K in the second (medium green) and third (light green) years. Figure 2 also demonstrates that a combination of nutrients is always the best performer in each crop even though no one combination has been consistent across all cropping years. In the first year it seemed that the PS combination was the best performer, in the second and third crops the PK combination was the best performer. It is also worth noting that the chickpea crop in 2013 showed visual symptoms of K deficiency (Photos below) which is possibly why the responses in 2013 were so strong (P:K = 51%, K= 28%).


Chickpea plants in control plot


Chickpea plants in a P:K plot

The overall response to the deep placement of fertiliser bands is always tempered by seasonal constraints and/or crop species sensitivity.

Table 2. Grain yield (t/ha) results across all treatments for all 3 crops harvested from the site since 2011

Site and crop/year	Control	K	P	S	PK	PS	KS	PKS	LSD (P<0.05)
Sorghum 2011/12	2.32	2.39	2.78	2.36	2.90	2.81	2.35	2.81	0.14
Chickpea 2013	1.15	1.47	1.32	1.21	1.74	1.18	1.52	1.61	0.26
Sorghum 2014/15	2.94	3.40	2.99	2.90	3.38	3.25	3.19	3.25	0.20

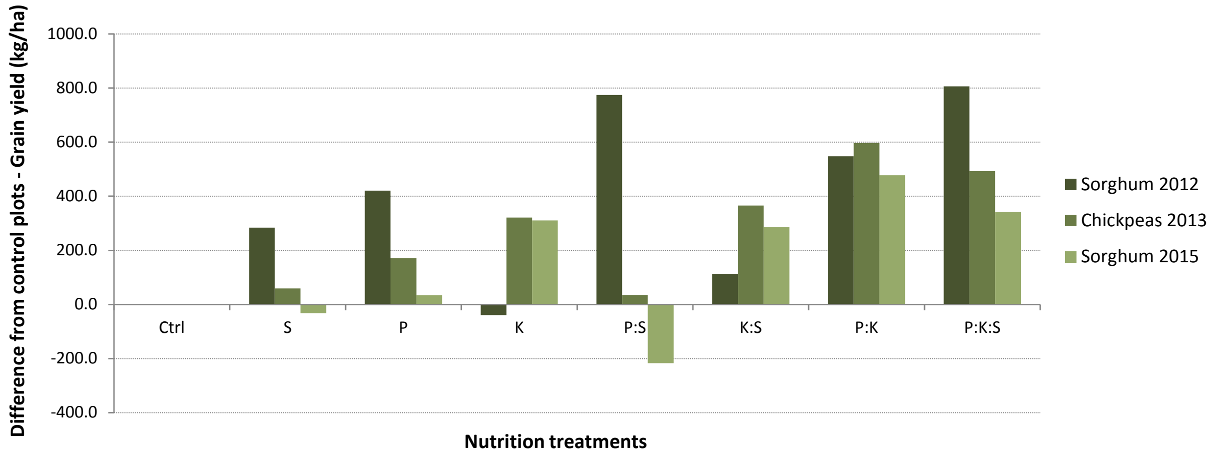


Figure 1. Comparison of grain yield (kg/ha) across three successive crops

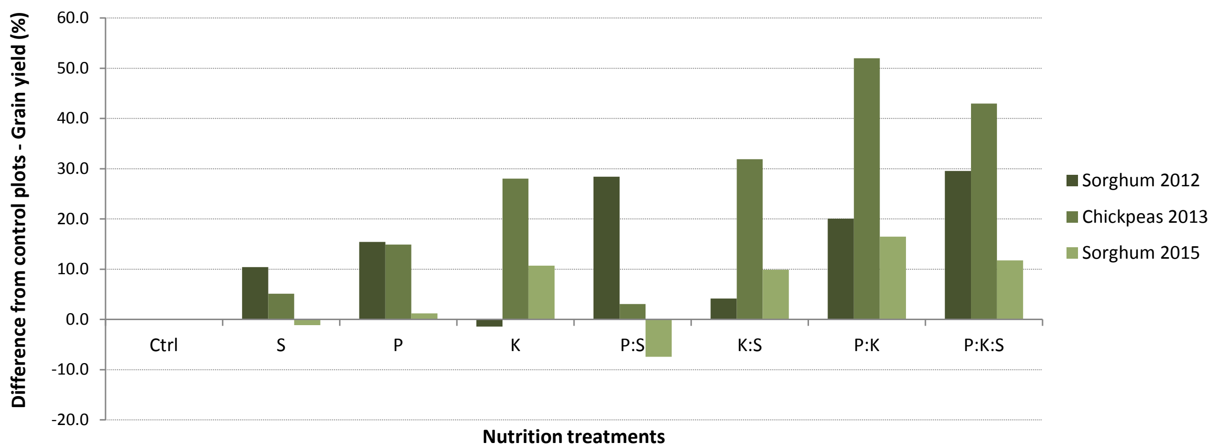


Figure 2. Comparison of grain yield (%) across three successive crops

Each of the treatments have managed to return a net positive, with P by itself providing the best Return on Investment (ROI), and P:K treatments providing the highest net benefit over the 3 years (Table 3). Current response rankings may be influenced by the sequence of crops following deep nutrition application with chickpeas showing larger K responses than P, if chickpeas had been priced at $800/t in 2014 then the ROI from P:K would be 5.2, whilst K by itself would be 3.3. Likewise if the rotation had been chickpea, sorghum, chickpea this may also have changed the ranking of results.

Table 3. Economics of deep nutrient placement after 3 years

	3 Year Benefit vs Control ($/ha)	Treatment Cost vs Control ($/ha)	3 year Net Benefit vs Control ($/ha)	ROI
Control	0	0	0	0.0
K	375	133	242	1.8
P	262	172	90	0.5
S	49	14	36	2.6
PK	714	305	409	1.3
PS	215	146	68	0.5
KS	359	186	173	0.9
PKS	559	318	240	0.8

Note: Calculated assuming grain prices of $250/t sorghum (2012), $400/t chickpea (2013), $220 sorghum (2015)

The duration of response in each of these treatments, as well as sequence of crops grown in future years, will impact the final return on investment and total net benefit.

Table 4. Summary of in-crop rainfall for the 3 crops grown

Crop year	In-crop rainfall	Comments
2012 sorghum	540mm	35% post flower
2013 chickpeas	9mm	Small falls, no impact
2015 sorghum	244mm	96% prior to flowering

It is clear from Table 4 that the sorghum crops had the advantage of more in-crop rainfall than the chickpea crop and yet the response (in percentage terms) was strongest in the chickpea crop. This could be because the sorghum crops, due to higher in-crop rainfall, allowed them to access nutrients from the surface soil profile, whereas the chickpeas had to rely on stored soil moisture at depth, for the entire life of the crop.

Although there was a large difference in rainfall between the two sorghum crops there was almost no difference in the average yield for the trial site (2.917 t/ha in 2012, 3.037 t/ha in 2015). This potentially may have been a result of plant populations; the sorghum in 2012 established an average plant population of 24 000 plants/ha whereas the 2015 crop had an average plant population of 56 000 plants/ha.

The response to deep placed P and K can be influenced by the level of N available. A good indicator of N fertility is grain protein levels. Table 5 shows grain protein levels for selected treatments for the 2015 sorghum crop. Protein levels are above the critical point of 9.5% for all treatments and they are all remarkably similar. This would indicate that N was essentially non-limiting.

An issue for the deep placed fertiliser bands is whether the crops roots access this deeper zone. Analysis of the total dry matter (DM) shows K uptake increased by up to 50% and P uptake increased by up to 18% over the control plots. This would indicate that the crop did have access into these deep placed bands of nutrition, consistent with grain yield data which shows the main response at this site has been to the K treatments. The uptake figures show a much larger relative uptake of K over P in comparison to the control plots.

Implications for growers

This long term trial is showing good responses to deep placed P and K in consecutive crops of different species and root structures. This trial site is one of the few that is showing its most limiting nutrient is K first with an additive effect coming from P. The more common result is for P to be the most limiting with the additive effect coming from K, which was the case in the first

Table 5. 2015 sorghum results for grain protein, and phosphorus and potassium uptake in dry matter for selected treatments

Treatment	Avg grain protein (%)	Avg DM K uptake (kg/ha)	Rel difference to control for K uptake (%)	Avg of DM P uptake (kg/ha)	Rel difference to control for P uptake (%)
Control	10.4	53.7	0.0	8.4	0.0
K	10.2	80.6	50.1	9.6	13.9
P	10.4	55.8	3.8	9.4	11.0
P:K	10.2	77.5	44.3	9.3	10.8
P:K:S	10.2	83.3	55.1	10.0	18.6

crop grown at this site. It is not known why the pattern of responses to K in the sorghum crops has changed from 2012 to 2015.

Once again seasonal constraints and crop type all have an effect on the size of the response from deep placed nutrition particularly in relation to the non-mobile nutrients. The chickpea crop at this site had no in-crop rainfall and grew entirely on stored soil moisture with a spectacular 51% response to the P:K treatments whereas the following sorghum crop had a wet start and a dry finish and delivered a more conservative 16% response to the P:K treatment.

Further monitoring of this site in 2016 will show whether the response to deep place P and K will continue into a fourth crop.

Acknowledgements

It is greatly appreciated to have continued support of the co-operator, and for the hosting of this trial site.

This work has been supported by Canpotex P/L, International Plant Nutrition Institute (IPNI), the Grains Research and Development Corporation, the Department of Agriculture and Fisheries, and the Queensland Alliance for Agricultural and Food Innovation.

Trial details

Location:	Gindie
Crop:	Sorghum 2012, chickpea 2013, sorghum 2015
Soil type:	Brigalow scrub, cracking black/ grey vertosol
In-crop rainfall:	244 mm
Fertiliser:	110 kg/ha urea applied pre-plant (sorghum 2015) 20 kg/ha CK55s at planting

Selected soil fertility characteristics:

Depth (cm)	Col P (mg/kg)	BSES P (mg/kg)	PBI	Exc. K (meq/ 100g)	ECEC (meq/ 100g)
0-10	9	8	120	0.2	39.42
10-30	4	4	140	0.06	42.47
30-60	4	4	150	0.05	44.83

Gindie trial

Sorghum production four years after deep nutrient application - Capella

Doug Sands, Dr David Lester and James Hagan
Department of Agriculture and Fisheries

Research Question: *Does the application of immobile nutrients such as phosphorus and potassium continue to improve yields four years after the initial deep placement application?*

Key findings

1. No response to the deep placed treatments in the 2015 sorghum crop
2. Very small differences in the phosphorus uptake of the sorghum plant
3. Low grain proteins across the all treatments may indicate low nitrogen status for the site and this has influenced the results

Background

There is some soil testing evidence to suggest that nutrient stratification of non-mobile nutrients such as phosphorus (P) and potassium (K) is occurring across a range of Central Queensland (CQ) soil types. Nutrient stratification occurs when there is a redistribution of non-mobile nutrients through several crop cycles. Plants are taking up nutrients from the lower parts of the profile (10-30 cm) and these are then being released through stubble breakdown into the top 10 cm of the profile, where they stay because they are immobile elements. The problem is further enhanced by the application of starter fertilisers into the top 10 cm of the soil profile.

In CQ conditions many grain crops, both summer and winter, rely on stored moisture at depth to fill grain, as the top 10-15 cm is often too dry for plant roots to be active. Nutrients can only be taken up via soil moisture; consequently the majority of nutrients are sourced deeper in the profile (below 10-15 cm). If this zone is depleted in non-mobile nutrients grain yield can be limited.

This research is investigating if the application of P and K in the 10-30 cm zone of the soil profile can replenish this depleted zone sufficiently to improve yield (if other nutrients are non-limiting) and if this can last for multiple crop cycles.

Treatments

The treatments at this site were established in October 2011. The following crops have been planted:

- 2012 chickpeas
- 2013 wheat
- 2014 chickpeas
- 2015 sorghum

Each crop had starter fertiliser applied in the top 10 cm at planting and also additional nitrogen (N) was applied to the cereal crops such as wheat and sorghum (60-100 kg/ha of urea).

Table 1. Treatment description

		Nutrient applied (kg/ha)									
Trt No.	Treatment name	N	P	K	S	B	Cu	Fe	Mn	Mo	Zn
1	Control	100	-	-	-	0.8	0.8	2.2	1.8	0.04	2.5
2	P	100	40	-	-	0.8	0.8	2.2	1.8	0.04	2.5
3	K	100	-	200	-	0.8	0.8	2.2	1.8	0.04	2.5
4	S	100	-	-	40	0.8	0.8	2.2	1.8	0.04	2.5
5	P:K	100	40	200	-	0.8	0.8	2.2	1.8	0.04	2.5
6	P:S	100	40	-	40	0.8	0.8	2.2	1.8	0.04	2.5
7	K:S	100	-	200	40	0.8	0.8	2.2	1.8	0.04	2.5
8	P:K:S	100	40	200	40	0.8	0.8	2.2	1.8	0.04	2.5
9	Control-TE	100	-	-	-	-	-	-	-	-	-
10	P:K:S-TE	100	40	200	40	-	-	-	-	-	-

Note: Nitrogen (N), Phosphorus (P), Potassium (K), Sulfur (S), Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Zinc (Zn); TE= Trace elements

Table 2. Comparison of average grain yields (t/ha) across all nutrient treatments in three successive crops (2011-2014)

Site and crop/year	Control	K	P	S	PK	PS	KS	PKS	LSD (P<0.05)
Chickpea 2012	2.33	2.34	2.75	2.32	2.89	2.79	2.30	2.83	0.17
Wheat 2013	2.08	2.19	2.25	2.19	2.36	2.25	2.20	2.34	0.09
Chickpea 2014	1.51	1.59	1.57	1.53	1.69	1.65	1.60	1.75	0.10

There were 10 treatments applied across six replicates, with treatments described in Table 1.

Three control plots were used in each replicate to give a more realistic estimate of the average performance of the untreated plots, and also to assist with any subsequent analyses of spatial variability in the analysis of treatment effects. The trial had 12 plots per replicate and 72 plots for the whole trial. The treatment rates were split between a shallow (10 cm) and a deep (20 cm) application. The fertiliser bands were placed 40 cm apart with a fixed tine implement. The plots were 32 m long by 8 m wide and were split either side of the harvester tram tracks which were 9 m apart from centre to centre. Planter widths were 18 m wide from centre to centre. All crops were planted and sprayed by the grower co-operator as part of their normal management regime.

The 2015 sorghum crop had an additional 75 kg urea applied at planting along with 30 kg/ha of a starter blend similar to CK55. MR-Buster was planted at 50 000 seeds/ha on 1.5 m rows on 5 January 2015 and harvested on 24 April 2015. The crop received a total of 183 mm of rainfall with 85% of this falling in the first month after planting.

Total biomass samples were cut at maximum dry matter accumulation or when the grain was at the soft dough stage. These samples were dried, weighed and selected samples were ground for nutrient analysis. Grain yields were measured by harvesting two strips out of each plot with a plot harvester. After harvest weights were measured then selected grain samples were taken and ground for analysis. Grain yields were adjusted for moisture to a standard of 12.5%.

Results

Although this crop had a great start with plenty of in-crop rainfall it did have a dry finish which is typical for a CQ summer crop. This sort of scenario is where crops normally respond to deep placed fertiliser due to the plants accessing moisture and nutrients from deeper in the profile in order to flower and fill grain. This crop was double cropped from chickpeas, which increased the pressure on nutrient availability in the soil.

Figure 1 does not show any significant differences between treatments. The yield of all treatments was very consistent, with 88 kg/ha the total average difference between the lowest and highest treatment.

However, this site has shown some clear responses to P treatments, especially with the addition of K, across the previous three crops (Table 2).

Figure 2 shows the average differences between the treatments and the control plots are highlighted by using the control data as a zero baseline. This indicates that the site has been mostly responsive to P as any treatment with P in it, either on its own or in combination, has consistently given the largest response. There has also been an additive response from the other elements such as K and S on top of the P response. P must be the first limitation as K and S on their own do not show any significant difference in grain yield.

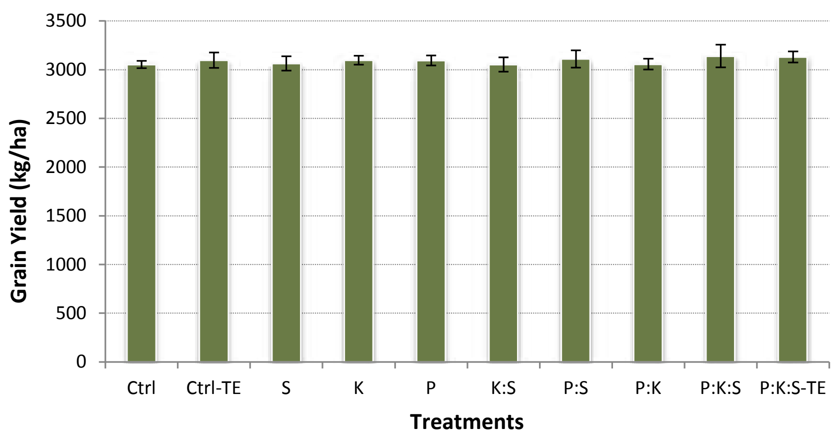


Figure 1. Grain yield responses to deep placement of nutrients - Sorghum 2015

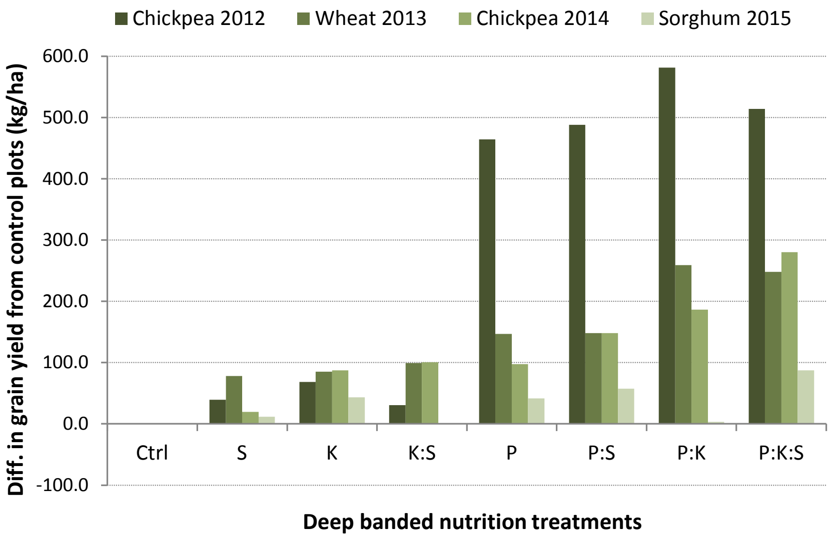


Figure 2. Comparison of grain yield data (kg/ha) across four successive crops

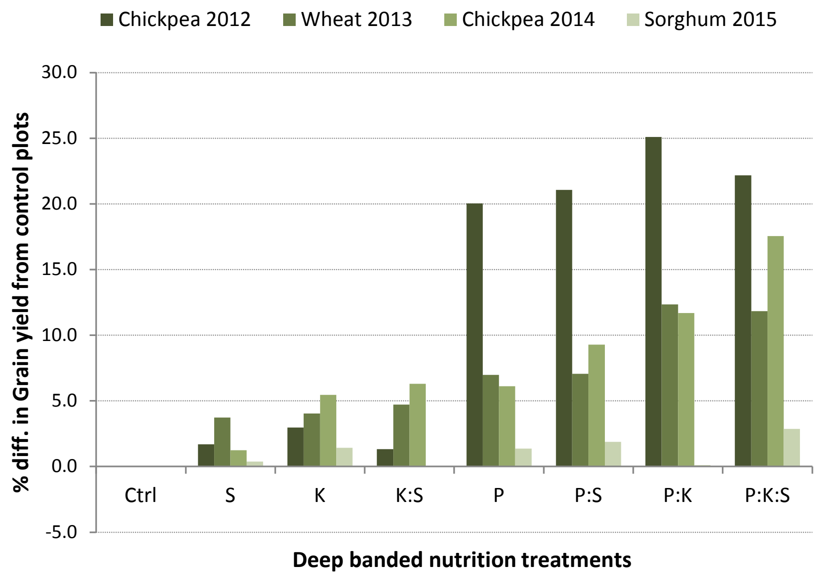


Figure 3. Comparison of grain yield data (%) across four successive crops

Figure 3 provides a summary of the performance of the different treatments across the site over the last four years (including 2015 sorghum data). The same yield data is used as Figure 2 but presented as a percent difference to the control plots. Each different colour represents a different crop and season.

The overall response to the deep placement of fertiliser bands has been tempered by seasonal constraints and/or crop species sensitivity. In the first year of production there was a 20% average yield response (Figure 3) in the first chickpea crop across all the P treatments. In subsequent years this response was less than 10% for P on its own or in combination with S.

However treatments with P and K together have been above 10% even in water limited scenarios (Table 4). The P response percentage is slowly decreasing over time which may indicate that the 40 kg P/ha applied in 2011 has been utilised by the four following crops. It will be interesting to see the yield response in year five.

Seasonal conditions would also have impacted upon crop response. The wheat crop in 2013 had no secondary root system; therefore, the amount of root surface area in contact with the fertiliser band was limited. The following chickpea crop was also moisture limiting for much of the crop cycle, however chickpeas being a tap rooted species seemed to have a stronger response particularly to the combination of P and K.

All treatments that included deep P have returned a positive net benefit over the four years ranging from $37 to $121/ha, with P by itself providing the greatest return on investment. It appears as though the majority of the benefit so far can be attributed to P, however had chickpea prices been $800/t in 2014 rather than closer to $400/t the P:K and P:K:S treatments would both have more attractive ROIs at 0.5 and 0.4 respectively,

Table 3. The economics of deep nutrition after 4 years

	4 Year Benefit vs Control ($/ha)	Treatment Cost vs Control ($/ha)	4 year Net Benefit vs Control ($/ha)	ROI
Control	0	0	0	0
K	80	172	-92	-0.5
P	253	133	121	0.9
S	40	54	-14	-0.3
PK	381	305	76	0.2
PS	305	187	118	0.6
KS	60	226	-167	-0.7
PKS	396	359	37	0.1

Note: Calculated assuming grain prices of $400/t chickpea (2012 & 2014), $300/t wheat (2013), $250 sorghum (2015) generating net benefits of $148 and $133/ha (Table 3).

Deep P's first year returns were great enough to pay the treatment off, meaning any future benefits would go straight to profit, none of the deep nutrient treatments without P have so far been able to generate positive net benefits. Further monitoring will be required to determine whether there are carryover effects into year five which may change the rankings of returns.

Table 4. Summary of in crop rainfall for the four successive crops

Crop year	In-crop rainfall	Comments
2012 chickpeas	98 mm	96% of rainfall prior to first flower
2013 wheat	15 mm	Small falls, no impact
2014 chickpeas	147 mm	10% of rainfall in first 100 days of crop
2015 sorghum	171 mm	89% of rainfall in first 30 days of crop

The generally dry conditions that have prevailed across most of the crops grown at this site (Table 4) make it difficult to ascertain whether the yield responses that have been recorded from this site are a true reflection of the nutrient depletion or have been modified by moisture limitations.

Figure 4 illustrates that the accumulated P uptake from the first three crops amounts to about 22 kg/ha which represents about 55% of the original amount of P that was first applied in 2011 (40 kg/ha). However in the same time the control plots have accumulated 15 kg of P in dry matter which means the treated plots have only contributed an extra 7 kg/ha of P over and above the native fertility. Although there was still a difference between the P uptake of the control plots and the other treatments in the 2015 sorghum crop, the difference was only 10% and had no impact on grain yield, compared to about 75% in the first crop planted after the treatments were applied.

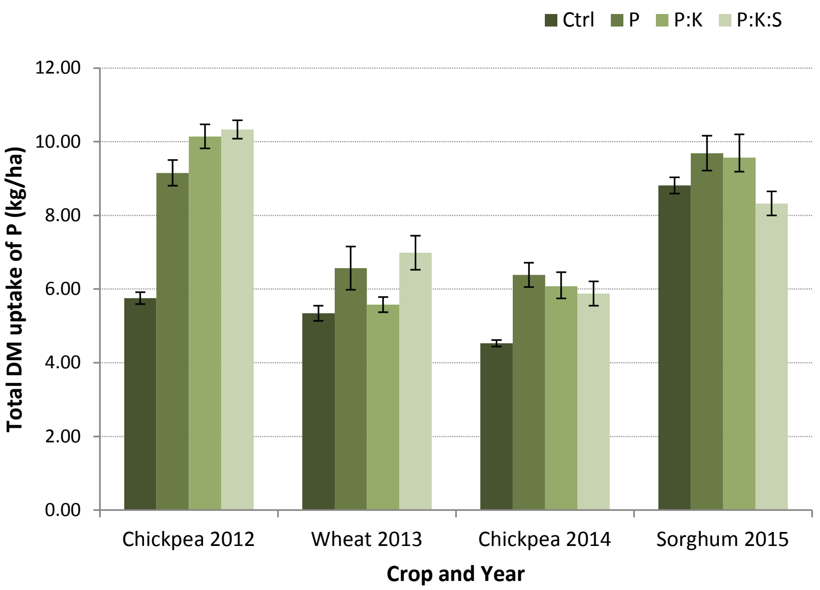


Figure 4. Comparison of phosphorus uptake of selected treatments across years

Over the four crops to date, the P treatments have accumulated an extra 8 kg of P/ha over the control plots. This amounts to only 20% of the original amount of P that was first applied (40 kg/ha). However the original applications were split between two depths (10 cm and 20 cm). If we assume that most of the extra P was contributed by the deepest bands because of the dry surface layers, then the 8 kg of P has come from a 20 kg band. This would then mean recovery is closer to 40% of the original application. The best response was in the first year when the bands would have been at their highest concentration and root development was enhanced by reasonable in-crop rainfall prior to first flower. It is unknown whether the P uptake has been influenced by dry conditions and poor root access, or if there has been a decline in the availability of the nutrients from the original bands of fertiliser over time.

The buffering index for this site is less than 150 in the top 60 cm of the profile. In general terms this index is considered low in relation to the soils ability to reabsorb P and make it temporarily unavailable; therefore P absorption at this site should only be a minor consideration.

Soil nitrogen may also be potentially impacting on yield response. Soil tests done at the beginning of the 2014 chickpea crop indicated about 41 kg of N in the profile down to 120 cm. No additional N was added for this chickpea crop. There was 75 kg of urea (35 kg N/ha) added at planting for the 2015 sorghum crop. Assuming there was very little N left over from the chickpea crop and there was insufficient time for the residual stubble to have broken down; the total available N for the sorghum crop would include 35 kg of N from urea and possibly 15 kg of N from mineralisation over the 3 months. Early rainfall in the first 30 days of the crop's

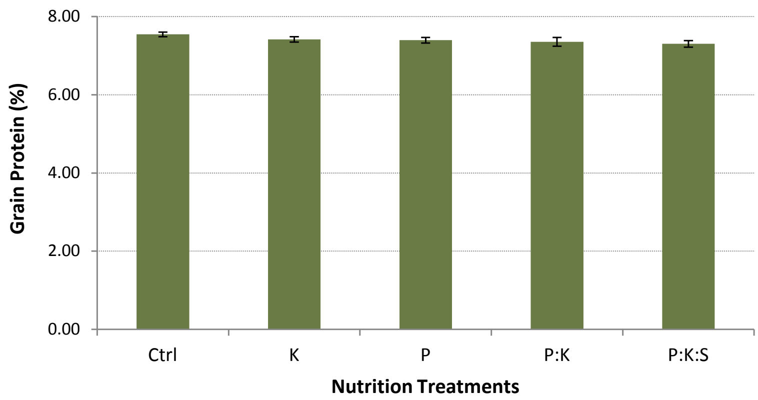


Figure 5. Comparison of grain protein between selected treatments (sorghum 2015)

life (90% of 171 mm), may have triggered some denitrification from the urea application (estimate 20% losses). Therefore total N available to the crop may not have exceeded more than 45 kg/ha. Theoretically the crop required about 80 kg of N/ha to maximise yield.

Figure 5 shows grain protein data for selected treatments from the trial site for the 2015 sorghum crop. This data has been calculated from the N content in the grain analysis. The data presented shows an average grain protein of just 7.5% which indicates grain yields at this site were strongly N limited. This may explain why there are no significant differences between treatments. The protein contents were uniformly low across the control plots and all other treatments, again consistent with a primary yield limitation from N deficits.

Implications for growers

The longevity and efficacy of deep placement of P based fertilisers on cracking vertosol soils is dependent on a number of variables. These variables include crop species, variations of in-crop rainfall, yield, concentration of the fertiliser band, native fertility levels particularly nitrogen, buffering capacity of the soil and also possibly row spacing intervals. Responses to deep placed P in a soil with a depleted layer can vary from over 20% down to under 10%. The addition of K with P on this soil type has improved the reliability of the response in grain yield with the P:K treatments generally out yielding the P treatment by an extra 5% across the first three crops and maintained an overall yield response of above 10% against the control treatments in all three of these crops.

In this situation, we are unable to determine the longevity of the deep applied P, as the apparent disappearance of the P response in this fourth crop year may be due entirely to the inadequate supply of N to maximise yield response. This issue seems to be a significant challenge for growers, in that if potential yields are being raised by 15-20% by overcoming P, K and/or S limitations, there has to be a concurrent increase in site N supply (typically via increased fertiliser N inputs) to be able to achieve this higher productivity. Soils are increasingly relying on fertiliser nutrient inputs to meet water limited yield potentials, so unless growers are prepared to mix and match those inputs to suit the sites and yield potentials they are targeting, they will not see the benefits from improved soil fertility.

Further monitoring in 2016 will give us more data on the longevity of these applications.

Acknowledgements

It is greatly appreciated, for the continued support of the co-operators for hosting this trial site.

This work has been supported by Canpotex P/L, International Plant Nutrition Institute (IPNI), the Grains Research and Development Corporation, the Department of Agriculture and Fisheries and the Queensland Alliance for Agricultural and Food Innovation.

Trial details

Location:	North-west of Capella
Crop:	chickpea (2012), wheat (2013), chickpea (2014), sorghum (2015)
Soil type:	Downs, cracking black vertosol
In-crop rainfall:	171 mm
Fertiliser:	30 kg/ha CK55 or equivalent at planting plus 75 kg/ha of Urea (sorghum 2015)

Selected soil fertility characteristics for the trial site:

Depth (cm)	Col P (mg/kg)	BSES P (mg/kg)	PBI	Exc. K (meq/100g)	ECEC (meq/100g)	Sul - KCl40 (mg/kg)
0-10	10	20	118	0.31	56.37	1.6
10-30	3	15	132	0.13	56.82	3.2
30-60	1	12	151	0.1	58.29	1.8

The value of deep placed phosphorus, potassium and sulfur in scrub soils - Kilcummin

Doug Sands, Dr David Lester and James Hagan
Department of Agriculture and Fisheries

Research Question: *Does the deep placement of phosphorus (15 to 20 cm), potassium and sulfur have an impact on chickpea yields?*

Key findings

1. Clear response to deep placement of phosphorus in grain yield (21-24%)
2. Additive effect of deep place potassium in grain yield (6-8%)
3. No response to sulfur

Background

There is some soil testing evidence to suggest that nutrient stratification of non-mobile nutrients such as phosphorus (P) and potassium (K) is occurring across a range of Central Queensland (CQ) soil types. Nutrient stratification occurs when there is a redistribution of non-mobile nutrients through several crop cycles. Plants are taking up nutrients from the lower parts of the profile (10-30 cm) and then being released through stubble breakdown into the top 10 cm of the profile where they then stay because they are immobile elements. The problem is further enhanced by the application of starter fertilisers into the top 10 cm of the soil profile.

In CQ conditions many of our grain crops, both summer and winter, rely on stored moisture to fill grain as the top 10-15 cm is too dry for plant roots to be active. Nutrients can only be taken up via soil moisture; consequently most of the plant nutrients are sourced deeper in the profile (below 10-15 cm). If this zone is depleted in non-mobile nutrients grain yield can be limited.

This research is investigating if the application of P and K in the 10-30 cm zone of the soil profile can replenish this depleted zone enough to improve yield in the presence of other non-limiting nutrients, and to determine if this replenishment can last for multiple crop cycles.

Treatments

The treatments at this site were established in February of 2015 and the first crop on the site was chickpeas harvested in September 2015.

Phosphorus trial:

There were eight treatments in total, which included four P rates; 0, 10, 20, and 40 kg P/ha. All of these treatments had background fertiliser applied at the same time to negate any other limiting nutrients. This background fertiliser included; 80 kg/ha nitrogen (N), 50 kg K/ha, 20 kg/ha sulfur (S) and 1 kg/ha Zinc (Zn). The other treatments included 0P and 40P without any background fertiliser except N and Zn (0P-KS, 40P-KS). The last two treatments were farmer reference (FR) plots and an extra 0P plot was added to give two controls for each replicate. The FR treatments had nothing applied except what the farmer applied in line with normal commercial practice. Table 1 lists the commercial fertiliser products that were used, and Table 2 gives a summary of the treatments.

These treatments were applied using a fixed tyne implement which delivered the P and K 20 cm deep and the N and S 10-15 cm deep. The bands of fertiliser were placed 50 cm apart in plots that were 8 m wide by 32 m long. The bands were place in the same direction as the old stubble rows. There were six replicates used making a total of 48 plots for the trial.

The 2015 crop received a liquid starter at planting. This liquid starter comprised of CalSap®, Fine Phosphate, Urea Ammonium Nitrate (UAN) and Potassium sulfate. The total rate and analysis of this liquid starter is approximately, 2 kg N : 5 kg P : 5 kg K : 2 kg S : 0.3 kg Calcium : 0.5 kg Magnesium. Chickpeas were planted into the site 5 May 2015 and harvested 28 September. The crop was planted on 1.5 m rows and due to a lack of planting rain, the crop was deep sown at a depth of 15-20 cm. There was almost no in-crop rainfall.

Potassium trial:

There were eight treatments in total which included four K rates; 0, 25, 50, 100 kg K/ha. All treatments had background fertiliser applied at the same time to negate any other limiting nutrients. This background fertiliser included; 80 kg N/ha, 20 kg P/ha, 20 kg S/ha and 1 kg Zn/ha. The other treatments included 0K and 100K without any background fertiliser except N and Zn (0K-PS, 100K-PS). The last two treatments were a farmer reference and an extra 0K to give two controls in each replicate. The FR plots were not treated with anything except what the farmer applied in line with normal commercial practice.

Applications were done in the same way as the P trial and the other trial details remain the same (Table 2).

Sulfur trial:

There were eight treatments in total which included four S rates; 0, 10, 20, 30 kg S/ha. All of these treatments had background fertiliser applied at the same time to negate any other limiting nutrients. This background fertiliser included; 80 kg N/ha, 20 kg P/ha, 50 kg K/ha and 1 kg Zn/ha.

The other treatments included 0S and 30S without any background fertiliser except N and Zn (0S-PK, 30S-PK). The last two treatments were similar to the other trials with an extra 0S treatment being included as another control and a farmer reference treatment (Table 2).

Table 1. Commercial products used in nutrient treatments

Nutrient	Product source of nutrient in applications
Nitrogen (N)	Urea (46%), MAP (10%), GranAm (20%)
Phosphorus (P)	MAP (22%)
Potassium (K)	Muriate of Potash (50%)
Sulphur (S)	GranAm (24%)
Zinc (Zn)	Agrichem Supa zinc (Liq) (7.5%w/v)

Table 2. Summary of nutrient application rates for all treatments

Trial	Treatment Label	N rate (kg/ha)	P rate (kg/ha)	K rate (kg/ha)	S rate (kg/ha)	Zn rate (kg/ha)
Phosphorous (P)	0P	80	0	50	20	1
	0P	80	0	50	20	1
	10P	80	10	50	20	1
	20P	80	20	50	20	1
	40P	80	40	50	20	1
	0P-KS	80	0	0	0	1
	40P-KS	80	40	0	0	1
	FR	0	0	0	0	0
Potassium (K)	0K	80	20	0	20	1
	0K	80	20	0	20	1
	25K	80	20	25	20	1
	50K	80	20	50	20	1
	100K	80	20	100	20	1
	0K-PS	80	0	0	0	1
	100K-PS	80	0	100	0	1
	FR	0	0	0	0	0
Sulfur (S)	0S	80	20	50	0	1
	0S	80	20	50	0	1
	10S	80	20	50	10	1
	20S	80	20	50	20	1
	30S	80	20	50	30	1
	0S-PK	80	0	0	0	1
	30S-PK	80	0	0	30	1
	FR	0	0	0	0	0

Results

Total plant dry matter samples were cut 7 September from all three trials. All plots were sampled except the extra zero plots. Samples were dried and weighed before being ground and a sub sampled sent for total nutrient analysis.

Grain yield was measured by harvesting the middle two rows of each plot with a plot harvester on 28 September. Grain yield was corrected for moisture with all plots brought back to a receival moisture of 12.5%. A sub sample of grain was taken for each plot, ground and sent for total nutrient analysis.

Phosphorus trial

The yield data in Table 3 clearly shows a response to the deep placed P treatments with a 20-30% increase in yield across all treatments that had P added (400–550 kg/ha). It is also worth noting that where the background K and S was not added to the highest rate of P, that there was a drop in yield of nearly 6%. This response was not replicated at the 0P rate which might indicate that there may be an additive effect from the K and S once P demand was met. The overall response to K and S should be better defined in the K and S trial.

Another point worth noting is that there is almost a response curve occurring with the increasing concentrations of P. This could be because the relative increase in concentration gradients across the different treatment bands of fertiliser contributed more to root uptake although this is difficult to prove. Analysis of the total dry matter uptake of P across all treatments (Figure 1) in the P trial demonstrates an increase in uptake of P between the 10P rate and the 20P rate. In contrast to this there is no difference between the 20P and the 40P rates. Hence it is inconclusive whether the concentration of the banded fertiliser is having an impact on the relative uptake of P and consequently the grain yield. It is clear (Figure 1) that the roots of the crop are accessing the extra P from the deep banded applications.

Table 3. Comparison of average grain yields across treatments in phosphorus trial

Treatment	Grain Yield (kg/ha)	Relative Yield Difference to '0P plots' (kg/ha)	Relative Yield Difference to '0P plots' (%)
FR	1833 a	-8	-0.4
0P-KS	1885 a	44	2.4
0P	1841 a	0	0.0
10P	2243 b	402	21.8
20P	2345 bc	504	27.4
40P	2394 c	553	30.0
40P-KS	2285 bc	444	24.1

Means with the same letters are not significantly different at the 5% level

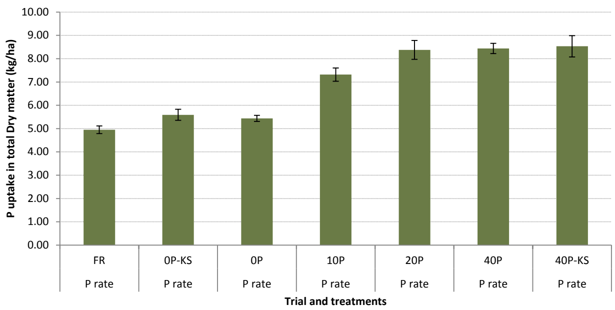


Figure 1. Total phosphorus uptake in dry matter across treatments

Table 4. Economic summary of phosphorus trial

	Benefit vs Farm Reference (kg/ha)	Benefit vs Farm Reference ($/ha)	Treatment Cost ($/ha)	Net Benefit vs Farm Reference ($/ha)	ROI
FR	0	0	0	0	0
0P-KS	52	42	93	-51	-0.6
0P	8	6	163	-157	-1.0
10P	410	328	193	135	0.7
20P	512	410	222	188	0.8
40P	561	449	281	168	0.6
40P-KS	452	362	211	151	0.7

One consideration for ongoing monitoring of this site is the fact that the phosphorous buffering index (PBI) for this soil type is just over the 150 level (152-158) and may decrease the availability of P from the deep bands over time.

With chickpea prices at $800/t each of the treatments in which deep P was applied provided a significant net benefit in the first year, ranging from $135 to almost $188/ha (Table 4). These benefits are very conservative as they include the total treatment costs of $30/ha application costs, $61/ha N, $2/ha Zn, K and S of $43 and $27/ha where applied and variable P costs of $3/kg. Given the lack of response to N, K, Zn and S at the 0P rate, it would not be unreasonable to assume that these costs would not exist in a typical paddock scenario, which would increase each of the P treatment net benefits by $130/ha.

The 20P treatment has currently provided the greatest Return on Investment (ROI), however it would be expected that 40P will provide a longer lasting benefit and rapidly increase in future years, given there is currently only $20/ha difference in net return between these treatments.

Potassium trial

There has been a small response to K (2-9%) (Table 5). Soil test results indicate that K levels are marginal but not as deficient as P (Trial details). There is a dramatic decrease in yield when P is excluded from the background nutrition (15-18%). In relative terms the P levels are far more critical (low) according to the soil test values than the K readings, hence it is not surprising that the trial indicates P is the most limiting nutrient. There is an additive effect from K, particularly at the higher rates (50K and 100K).

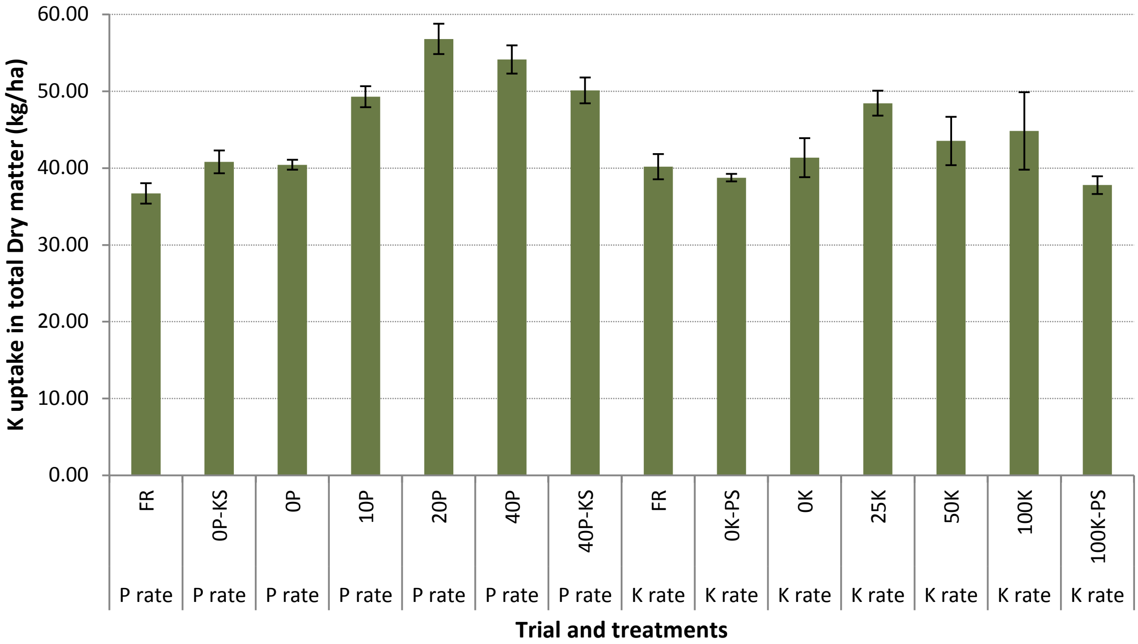


Figure 2. Total potassium uptake in dry matter across treatments

One of the major variables with deep placement fertiliser trials is how well the plants' root system can access the bands of nutrients. While grain yield improvements give an indicator of this, plant analysis of the total dry matter is also a good indicator of the level to which plants utilised the applied nutrient and also highlights the interaction between major nutrients.

Figure 2 shows that within the P trial all treatments that had P applied accessed more K (at least an extra 10 kg/ha). Additionally when K was not present in conjunction with a high P rate (40P-KS) there was a drop off in K uptake. This indicates that the plant was accessing K from the banded application, also when the most limiting nutrient is corrected it increases the uptake of the other major nutrients.

Dry matter analysis from the K trial (Figure 2) shows some improved uptake of K at the lower rate (25K) but not at the higher rates (50K and 100K). This may indicate that root access is limited around the more concentrated bands due to salt index issues. The data also indicates that when background P is removed, K uptake is reduced (100K-PS), which is a similar pattern to the P trial. Overall the K trial data indicates that while the crop roots are accessing the banded fertiliser, the plant is also accessing large proportions of its K supply from native fertility despite the marginal soil test levels.

A large proportion of the response seen in the deep K treatments appear to be in response to the background P application, as observed in the significant difference between the 0K and 0K-PS and FR treatments. The treatment costs include $30/ha in application, $61/ha N, $2/ha Zn, P and S costs of $59 and $27/ha where applied, and a variable K cost of $0.86/kg. Whilst there does not appear to be a significant difference between 0K and 25K, 50K and 100K both show some additional benefit over the background P application, providing approximately $70/ha in net benefit over 0K. The lack of response in treatment 100K-PS, strongly suggests that P is the limiting nutrient and that there is no benefit to K nutrition at this site unless P is above the critical limit.

Table 5. Comparison of average grain yields across treatments in potassium trial

Treatments	Grain Yield (kg/ha)	Relative Yield Difference to '0K plots' (kg/ha)	Relative Yield Difference to '0K plots' (%)
FR	1767 a	-373	-17.4
0K-PS	1814 a	-326	-15.2
0K	2156 b	16	0.7
25K	2179 bc	39	1.8
50K	2297 cd	157	7.3
100K	2342 d	202	9.4
100K-PS	1758 a	-382	-17.9

Means with same letters are not significantly different at the 5% level.

The 50K treatment currently shows the greatest ROI however this may change as the difference in duration of 50K and 100K will be observed over future years, it is also possible that this site may be again P limited before full K responses are realised (Table 6).

Table 6. Economic summary of the potassium trial

	Benefit vs Farm Reference (kg/ha)	Benefit vs Farm Reference ($/ha)	Treatment Cost ($/ha)	Net Benefit vs Farm Reference ($/ha)	ROI
FR	0	0	0	0	0.0
0K-PS	47	38	93	-55	-0.6
0K	389	311	179	132	0.7
25K	412	330	200	129	0.6
50K	530	424	222	202	0.9
100K	575	460	265	195	0.7
100K-PS	-9	-7	179	-186	-1.0

Sulfur trial

Table 7 shows the unusual situation of every treatment having a lower grain yield than the 0S treatment with background fertiliser indicating that there has been no response to the addition of S at this site. The reductions in yield when the background P and K are left out of the treatment is close to 20% which is once again a similar difference to what has been recorded in the other trials.

Table 7. Comparison of average grain yields across treatments in the sulfur trial

Treatments	Grain Yield (kg/ha)	Relative Yield Difference to '0S plots' (kg/ha)	Relative Yield Difference to '0S plots' (%)
FR	1952	-508	-21
0S-PK	1989	-471	-19
0S	2460	0.00	0.00
10S	2414	-46	-2
20S	2382	-78	-3
30S	2420	-40	-2
30S-PK	2069	-391	-16

*No significant differences in the means

It is also worth noting across all three trials that the differences between the FR plots and the 0 plots without background nutrition was very small which indicates that the additional N application and the ripping effect is not having any benefit to grain yield. This is not unexpected in a grain legume species although it is widely thought that chickpeas will utilise free nitrates before fixing its own N.

The NIR protein results from these trials also confirm that the protein contents across the treatments are relatively uniform and have been maintained at a high level (23-24%). Therefore access to N must have also been reasonably uniform across the site.

There was no economic response to the addition of S in any of the treatments in the first year, with the entire benefit attributable to the background P and K treatments ($212/ha), this is reflected in the 0S treatment having the highest ROI (Table 8). As per the P and K trials treatment costs include $30 application $61 N, $2 Zn, P and K of $59 and $43/ha where applied, as well as a variable S cost of $1.36/kg.

Table 8. Economic summary of the sulfur trial

	Benefit vs Farm Reference (kg/ha)	Benefit vs Farm Reference ($/ha)	Treatment Cost ($/ha)	Net Benefit vs Farm Reference ($/ha)	ROI
FR	0	0	0	0	0.0
0S-PK	37	30	93	-63	-0.7
0S	508	406	195	212	1.1
10S	462	370	208	161	0.8
20S	430	344	222	122	0.5
30S	468	374	236	139	0.6
30S-PK	117	94	134	-40	-0.3

Visual differences in harvest maturity across plots. The early maturing plots correlated to the higher nutrition and higher grain yielding plots.

Implications for growers

The lack of planting rain and no in-crop rainfall meant this crop was totally reliant on stored soil moisture, resulting in the plant relying heavily on the nutrients provided below the 15 cm surface layer. In this situation the deep banded placement of P and K has had a significant effect on grain yield. The additional P and K being placed in the 10-30 cm zone has added an extra 550 kg/ha to the grain yield (30% improvement) at the highest P rate. Within this gain, about 6 – 8% can be attributable to K. Even though P was the main limiting factor at this site, the additional K has had an additive effective to create a larger response than just P on its own.

This trial site has demonstrated that deep placement of non-mobile nutrients in a depleted soil profile can make significant improvements to grain yield. Seasonal conditions will always impact on the size of the response to deep placement nutrition and the seasonal conditions experienced at Kilcummin in 2015 were ideally suited to get a significant response. These crop responses for P and K are in line with the original soil test analysis; however there is still a major disconnect between the response to S and the soil test results for S.

Acknowledgements

The team greatly appreciates the continued support of the co-operators for hosting this trial site.

This work is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ00063 'Regional soil testing guidelines for the northern grains region'.

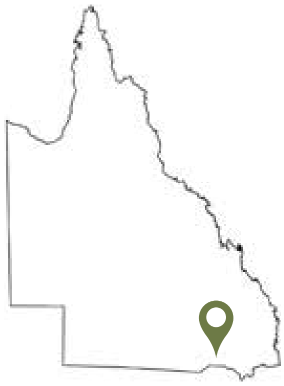
Trial details

Location:	Kilcummin
Crop:	Chickpea (Kyabra^(PBR))
Soil type:	Grey vertosol (Gidgee/Brigalow scrub) on alluvial flood plain
Fertiliser:	Liquid starter mix consisting of; 5 L CalSap®, 5 kg P (Fine Phosphate), 5 L UAN, 5 kg K (potassium Sulphate)applied on a per hectare basis.
In-crop rainfall:	4.5 mm

Selected soil fertility characteristics for the Kilcummin trial site

Depth (cm)	Col P (mg/kg)	BSES P (mg/kg)	PBI	Exc. K (meq/100g)	ECEC (meq/100g)	Sul - KCl40 (mg/kg)	N - No3 (mg/kg)
0-10	6	13	158	0.65	54	2.2	20
10-30	1	7	152	0.25	54	1.5	7
30-60	1	4	155	0.26	53	2.1	8

Starter and deep phosphorus improve chickpea phosphorus status, but not grain yield - Westmar



Dr David Lester[1] and Prof Michael Bell[2]
1 Department of Agriculture and Fisheries
2 University of Queensland

Research Questions: *Does putting phosphorus (an immobile nutrient) in the soil at 15-20 cm deep increase grain yields on the Western Downs? | How does starter phosphorus interact with deep placed phosphorus?*

Key findings

1. Starter phosphorus increased above ground dry matter at maturity and was very well used by the crop, but had no effect on chickpea yield
2. Deep phosphorus further increased crop phosphorus uptake above the starter application, but also had no effect on chickpea yield
3. Understanding of the relationship between chickpea physiology and phosphorus nutrition remains unclear

Background

As the age of cropping land increases, immobile nutrients such as phosphorus (P) are being retrieved by plants from the soil in the 10-30 cm layer. Application of starter fertiliser and return of crop residue to the soil surface is depositing these nutrients into this layer, creating a stratified distribution of higher availability in the surface and lower availability below. Root activity in the soil surface can be limited through faster loss of soil moisture, while deeper soil layers can offer longer periods of root activity as they are not as subject to evaporative moisture loss.

This research is questioning if placing immobile nutrients into the soil between 15-20 cm deep can increase grain yield, and how starter P interacts with this practice.

Treatments

Treatments were established in December 2012.

1. farmer reference - untreated control (representative of district production practice) (FR)
2. deep ripped only (0P)
3. 5 kg P/ha (5P)
4. 10 kg P/ha (10P)
5. 20 kg P/ha (20P)
6. 40 kg P/ha (40P)
7. 80 kg P/ha (80P)

Each deep P rate was split into two plots: one without starter (-Starter) and an adjacent plot with starter applied (+Starter) as the grower normally would.

Deep placement was between 15-20 cm deep with bands spaced 50 cm apart perpendicular to the sowing row. The additional phosphorus was applied as deep placed triple superphosphate (20% P). Additional basal application of 10 kg sulfur (S)/ha as ammonium sulfate, and 1 kg zinc (Zn) (as zinc chelate) were made into the fertiliser trench. There were six replicates.

Field crop history*:

- chickpea in 2013
- wheat in 2014
- chickpea in 2015

Above ground biomass was collected at physiological maturity (24 September 2015) and analysed for nutrient content via acid digestion and ICP (inductively coupled plasma) determination. Treatments sampled were Farmer Reference (FR), 0P and 20P both with and without starter, and 80P with starter.

Grain yield was measured using a plot harvester on 20 October 2015, and grain yield corrected to receival moisture of 13.5%.

P uptake in above ground dry matter (kg/ha) was calculated as the above ground dry matter (kg/ha) x P concentration (%), while grain P removed (kg/ha) was calculated as moisture corrected grain yield (kg/ha) x P concentration (%).

Results

Grain yield was not influenced by starter or deep-placed P application in 2015 (Figure 1).

*Note: only 2015 data is presented. A complete summary of all years' data is currently being compiled.

The trial yield averaged 2550 kg/ha overall, suggesting very good growing conditions for the year, which only received two in-crop rainfalls of over 25 mm.

Maturity dry matter cuts did indicate higher growth with deep placed P, increasing crop growth by roughly 10% at the 20 and 80P treatments (Figure 2).

P uptake was influenced by either a starter application, or a deep P application, but not the interaction between starter and deep P. Not applying starter reduced crop P uptake by 1.3 kg P/ha, which suggests the starter application of 5 kg P/ha (as TSP) is used very effectively by the crop. Uptake from the 20P treatment was 2.36 kg P/ha higher than both the FR and 0P treatments on 9.46 kg P/ha.

Effects on grain P removed matched those of the dry matter P uptake, with not applying starter reducing phosphorus removed by 1.3 kg P/ha: 7.15 kg P/ha for –starter vs 8.48 kg P/ha for +starter. There were no differences in P removed between FR (7.31 kg/ha) and 0P (7.44 kg/ha). 20P increased P removed in grain by 1.3 kg P/ha over the 0P treatment.

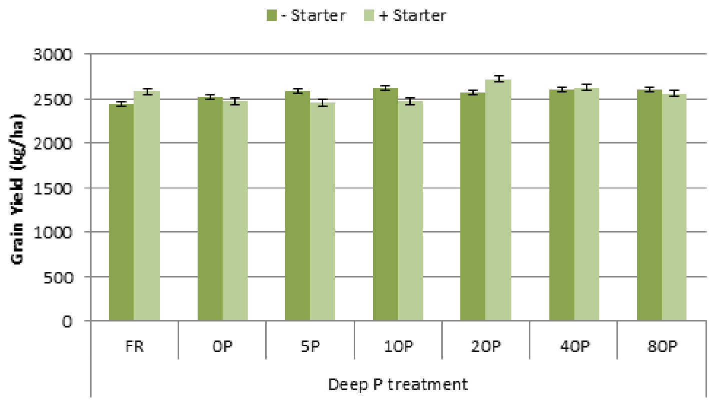


Figure 1. Chickpea grain yield without/with starter fertiliser application for deep-placed phosphorus treatments at Westmar in 2015.

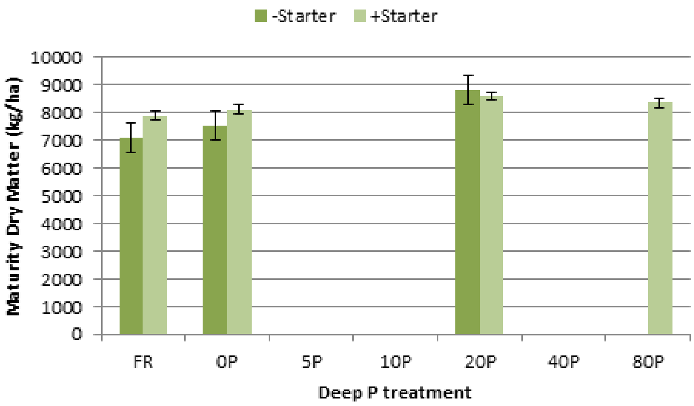


Figure 2. Maturity dry matter (kg/ha) for selected deep treatments without/with starter.

Implications for growers

The efficient recovery of starter P suggests growers continue to apply P with the chickpea seed at sowing.

Where deep P fits with the chickpea production system is a question needing further consideration, particularly in regards to two areas:

1. how P nutrition interacts with the flowering and pod setting (i.e. grain yield) physiology;
2. how should deep P be placed in the soil for recovery by chickpea crops.

With the grass crops (e.g. wheat/sorghum) a bigger plant usually equates to higher yield, but it appears that this doesn't necessarily apply to chickpea as the yield ability of the plant is influenced by additional environmental factors later in the growth cycle.

Additionally, with a coarser root system than grass crops, the recovery of the deep P bands by the crop could be limited. Further consideration of how to apply deep nutrients for recovery by these species is required.

Acknowledgements

The hosting of the site by the co-operators is greatly appreciated.

This work is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ00063 'Regional soil testing guidelines for the northern grains region'.

Trial details

Location:	Westmar
Crop:	Chickpea PBA HatTrick⁽ᴰ⁾ sown on 3 May 2015 at 63 kg/ha using 37.5 cm row spacing
Fertiliser:	TSP at 25 kg/ha in the seed row
Soil type:	Red chromosol
In-crop rainfall:	142 mm

Selected soil fertility characteristics for Westmar trial site:

Depth	Col P	BSES P	Ex K	ECEC
0-10 cm	16	52	1.14	22
10-30 cm	2	12	0.52	30

Chickpea yield increased with starter but not deep phosphorus - Ingelstone

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Research Questions: *Does putting phosphorus (an immobile nutrient) in the soil at 15-20 cm deep increase grain yields on the Western Downs? | How does starter phosphorus interact with deep placed phosphorus?*

Key findings

1. Starter phosphorus increased above ground dry matter at maturity, phosphorus uptake, grain yield and phosphorus removal
2. Deep phosphorus increased crop phosphorus uptake but had no effect on chickpea yield
3. Understanding of the relationship between chickpea physiology and phosphorus nutrition remains unclear

Background

As the age of cropping land increases, immobile nutrients such as phosphorus (P) are being retrieved by plants from the soil in the 10-30 cm layer. Application of starter fertiliser and return of crop residue to the soil surface is depositing these nutrients into this layer, creating a stratified distribution of higher availability in the surface and lower availability below. Root activity in the soil surface can be limited through faster loss of soil moisture, while deeper soil layers can offer longer periods of root activity as they are not as subject to evaporative moisture loss.

This research questions if placing immobile nutrients into the soil between 15-20 cm deep can increase grain yield, and how starter P interacts with this practice.

Treatments

Treatments were established in December 2012.

1. farmer reference - untreated control (representative of district production practice) (FR)
2. deep ripped only (0P)
3. 5 kg P/ha (5P)
4. 10 kg P/ha (10P)
5. 20 kg P/ha (20P)
6. 40 kg P/ha (40P)
7. 80 kg P/ha (80P)

Each deep P rate was split into two plots: one with zero starter (-Starter) and an adjacent plot with starter applied (+Starter) as the grower normally would.

Deep placement was between 15-20 cm deep with bands spaced 50 cm apart perpendicular to the sowing row. The additional P was applied as deep placed triple superphosphate (TSP) (20% P). Additional basal application of 10 kg sulfur (S)/ha as ammonium sulfate, and 1 kg zinc (Zn) (as zinc chelate) were made into the fertiliser trench. Every deep P plot received the equivalent of 60 kg N/ha. There were six replicates.

Field crop history*:

- wheat in 2013
- chickpea in 2014
- chickpea in 2015

Above ground biomass was collected at soft-dough stage (12 October) with two meters of two rows collected. Treatments sampled were FR, 0 and 20P both with and without starter, and 60P with starter. Above ground dry matter were dried to constant weight, weighed, ground and analysed for nutrient content via acid digestion and ICP (inductively coupled plasma) determination. Grain samples collected at harvest were ground and sent for chemical analysis also.

Grain yield was measured using a plot harvester on 18 November, and grain yield corrected to receival moisture of 12.5%.

P uptake in above ground dry matter (kg/ha) was calculated as the above ground dry matter (kg/ha) x P concentration (%), while grain P removed (kg/ha) was calculated as moisture corrected grain yield (kg/ha) x P concentration (%).

*Note: only 2015 data is presented. A complete summary of all years' data is currently being compiled.

Results

Starter application significantly increased grain yield ($p=0.001$) in 2015 (Figure 1). Yield was reduced by 131 kg/ha if starter was not applied. Grain yields achieved were supported by only two in-crop rainfalls of over 25 mm (in a 24 hour period).

Dry matter at maturity was also significantly reduced ($p=0.001$) by 1045 kg/ha (17%) by not applying starter. Above ground growth averaged 5189 kg/ha without starter and 6234 kg/ha with starter applied. Deep P had no significant effect on yield or dry matter production.

P uptake was significantly influenced by starter treatment ($p=0.001$) with not applying starter reducing the biomass P by 3.1 kg P/ha (6.76 kg P in –Starter and 9.87 kg P in +Starter), a 30% reduction. Given only 5 kg P/ha is applied as starter, this demonstrates very high recovery efficiency. The 20P treatment increased biomass P uptake ($p=0.05$) by 1.2 kg P/ha compared to the 0P treatment.

Grain P removed was higher in +Starter (8.34 kg/ha) than –Starter (6.51 kg/ha).

Implications for growers

While this is a later sown crop, the growth response and recovery of starter P suggests growers continue to apply P with the chickpea seed at sowing. How P changes chickpea physiology and influences yield parameters is a question requiring more investigation.

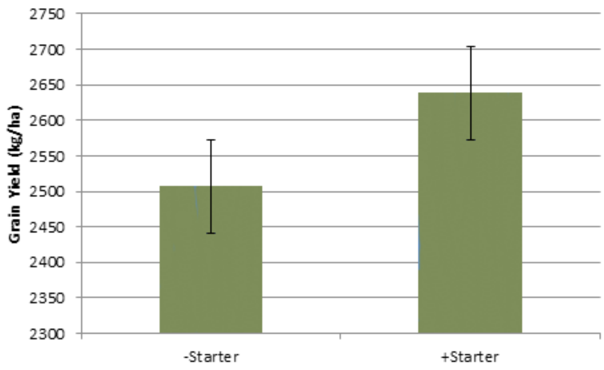

Figure 1. Grain yield without and with starter application in chickpea in 2015.

Acknowledgements

The hosting of the site by the co-operators is greatly appreciated.

This work is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ00063 'Regional soil testing guidelines for the northern grains region'.

Trial details

Location:	Ingelstone
Crop:	Chickpea PBA HatTrick⁽ᴰ⁾ sown on 28 May 2015 at 63 kg/ha using 37.5 cm row spacing
Fertiliser:	TSP at 25 kg/ha
Soil type:	Grey vertosol (Belah Brigalow)
In-crop rainfall:	142 mm

Selected soil fertility measures at Inglestone deep P trial site:

Depth	Col P	BSES P	Ex K	ECEC
0-10 cm	9	22	0.76	36
10-30 cm	4	13	0.44	40
30-60 cm	4	18	0.37	42

Application of deep phosphorus

Chickpea 2015

Wheat yield increased with starter and deep phosphorus - Goondiwindi

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Research Question: *Does putting phosphorus (an immobile nutrient) in the soil at 15-20 cm deep increase grain yields on the Western Downs? | How does starter phosphorus interact with deep placed phosphorus?*

Key findings

1. Combination of starter and deep placed phosphorus has increased grain yield by 480–660 kg/ha depending on variety
2. Higher yields also increase phosphorus removal rate

Background

As the age of cropping land increases, immobile nutrients such as phosphorus (P) and potassium (K) are being retrieved by plants from the soil in the 10-30 cm layer. Application of starter fertiliser and return of crop residue to the soil surface is depositing these nutrients into this layer, creating a stratified distribution of higher availability in the surface and lower availability below. Root activity in the soil surface can be limited through faster loss of soil moisture, while deeper soil layers can offer longer periods of root activity as they are not as subject to evaporative moisture loss.

This research is questioning if placing immobile nutrients into the soil between 15-20 cm deep can increase grain yield, and how starter P interacts with this practice.

Treatments

Treatments were established in May 2013.

1. farmer reference - untreated control (representative of district production practice) (FR)
2. deep ripped only (0P)
3. 10 kg P/ha (10P)
4. 20 kg P/ha (20P)
5. 30 kg P/ha (30P)
6. 60 kg P/ha (60P)

Each deep P rate was split into two plots: one without starter (-Starter) and an adjacent plot with starter applied (+Starter) as the grower normally would.

Deep placement was between 15-20 cm deep with bands spaced 50 cm apart perpendicular to the sowing row. The additional P was applied as deep placed mono-ammonium P (MAP) (10%N, 22% P). Additional basal application of 10 kg sulfur (S)/ha as ammonium sulfate, and 0.5 kg zinc (Zn) (as zinc oxide) were made into the fertiliser trench. Every deep P plot received the equivalent of 60 kg N/ha. There were six replicates.

Field crop history*:

- sorghum in 2013-14
- long-fallowed to wheat 2015

Above ground biomass was collected at soft-dough stage (12 October 2015) and analysed for nutrient content via acid digestion and ICP (inductively coupled plasma) determination. Treatments sampled were FR, 0P and 20P both with and without starter, and 60P with starter. Grain samples collected at harvest were ground and sent for chemical analysis also.

Grain yield was measured using a plot harvester on 18 November 2015, and grain yield corrected to receival moisture of 12.5%.

P uptake in above ground dry matter (kg/ha) was calculated as the above ground dry matter (kg/ha) x P concentration (%), while grain P removed (kg/ha) was calculated as moisture corrected grain yield (kg/ha) x P concentration (%).

Results

Inadvertently due to late night operations, two varieties were sown over the trial area – Spitfire(d) was planted over three and a half replicates and Sunvale(d) on the remaining two and a half replicates. The mid-June sowing for Sunvale(d) would be thought of as late in the district.

Dry matter was reduced by about 25% by not applying starter in the FR and 0P treatments for

*Note: only 2015 data is presented. A complete summary of all years' data is currently being compiled.

both Spitfire$^{\Phi}$ (Table 1a) and Sunvale$^{\Phi}$ (Table 1b). Deep P at 20 or 60P increased above ground crop growth by around 1500 kg/ha equalling about a 15% gain in both varieties.

Uptake of P by the above-ground dry matter again demonstrated the excellent recovery of starter fertiliser applied with seed at sowing with an increase of around 3 kg P/ha with +starter treatments compared to –starter in the FR and 0P plots, and 2-3 kg P/ha uptake increase in the 20P treatment.

Overall grain yield for farmer reference + starter treatments suggested a good growing season with some early in-crop rain helping to establish the crop and get secondary rooting/tillering underway. Grain yield was increased for both varieties with a starter application by 400 kg/ha for all treatments. Deep placement of P had a larger effect with Spitfire$^{\Phi}$ than Sunvale$^{\Phi}$. Average yield increases with 20P was 660 kg/ha with Spitfire$^{\Phi}$ vs FR+Starter while for Sunvale$^{\Phi}$ it was 480 kg/ha.

P removal in grain demonstrated the effect of starter application with generally less P removed in the –Starter treatments compared to the +Starter. The good seasonal conditions highlight how much P can be removed in higher yielding years.

Implications for growers

Long-fallow wheat yield at this site in this season has been increased through starter fertiliser application and use of deep placed P. Growing more above ground biomass has translated to more yield for this site.

Cumulative yield increase at this site for two crops (sorghum in 13-14 and wheat in 2015) is 730 kg/ha in the 20P treatment.

Acknowledgements

The hosting of the site by the co-operators is greatly appreciated.

This work is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ00063 ‘Regional soil testing guidelines for the northern grains region’.

Trial details

Location:	Goondiwindi
Crop:	Spitfire$^{\Phi}$ (3.5 reps) and Sunvale$^{\Phi}$ (2.5 reps) wheat sown on 09 June 2015 at 40 kg/ha using 33 cm row spacing
Fertiliser:	MAP at 40 kg/ha in the seed row at sowing
Soil type:	Grey vertosol (Belah Brigalow)
In-crop rainfall:	186mm

Selected soil fertility characteristics:

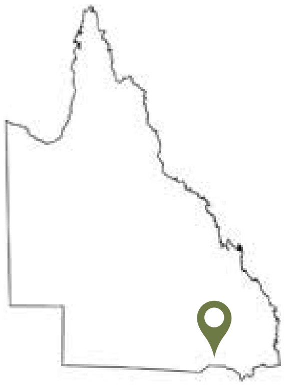
Depth	Col P	BSES P	Ex K	ECEC
0-10 cm	11	96	1.30	28
10-30 cm	<2	13	1.09	30
30-60 cm	<2	13	0.97	30

Table 1. Wheat dry matter, phosphorus uptake and grain yield of a) Spitfire$^{\Phi}$ and b) Sunvale$^{\Phi}$ without/with starter for deep placed phosphorus treatments

a)	Dry Matter (kg/ha)		DM P uptake (kg/ha)		Grain Yield (kg/ha)		Grain P rem (kg/ha)	
	-Starter	+Starter	-Starter	+Starter	-Starter	+Starter	-Starter	+Starter
FR	6973	9673	5.9	8.4	2997	3569	8.0	10.0
0P	7231	10537	6.2	9.9	2909	3315	6.2	7.1
10P					3292	3705		
20P	10043	11660	11.3	13.6	3703	4106	10.1	10.5
30P					4081	4248		
60P		11303		12.0	4078	4324		11.5

b)	Dry Matter (kg/ha)		DM P uptake (kg/ha)		Grain Yield (kg/ha)		Grain P rem (kg/ha)	
	-Starter	+Starter	-Starter	+Starter	-Starter	+Starter	-Starter	+Starter
FR	7260	8710	5.4	8.5	2713	3761	6.4	10.1
0P	7308	9597	5.9	8.9	3210	3901	7.9	10.0
10P					3290	3962		
20P	8290	10050	7.9	10.7	3260	4189	7.1	10.8
30P					3548	4134		
60P		10293		9.9	3838	4423		13.4

Deep phosphorus increased wheat yield but not biomass - Lundavra



Dr David Lester[1] and Prof Michael Bell[2]
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2 University of Queensland

***Research Questions:** Does putting phosphorus (an immobile nutrient) in the soil at 15-20 cm deep increase grain yields on the Western Downs? | How does starter phosphorus interact with deep placed phosphorus?*

Key findings

1. Using two machines to plant made establishing starter fertiliser response impossible. Grain yield responses to deep placed P were inconsistent, but crop growth was increased
2. Phosphorus export in grain can be higher than that applied in starter with above average grain yields, removing more phosphorus than is applied

Background

As the age of cropping land increases, immobile nutrients such as phosphorus (P) are being retrieved by plants from the soil in the 10-30 cm layer. Application of starter fertiliser and return of crop residue to the soil surface is depositing these nutrients into this layer, creating a stratified distribution of higher availability in the surface and lower availability below. Root activity in the soil surface can be limited through faster loss of soil moisture, while deeper soil layers can offer longer periods of root activity as they are not as subject to evaporative moisture loss.

This research is questioning if placing immobile nutrients into the soil between 15-20 cm deep can increase grain yield, and how starter P interacts with this practice.

Treatments

Treatments were established in December 2012.

1. farmer reference - untreated control (representative of district production practice) (FR)
2. deep ripped only (0P)
3. 5 kg P/ha (5P)
4. 10 kg P/ha (10P)
5. 20 kg P/ha (20P)
6. 40 kg P/ha (40P)
7. 80 kg P/ha (80P)

Each deep P rate was split into two plots: one without starter (-Starter) and an adjacent plot with starter applied (+Starter) as the grower normally would.

Deep placement was between 15-20 cm deep with bands spaced 50 cm apart perpendicular to the sowing row. The additional P was applied as deep placed triple superphosphate (TSP) (20% P). Additional basal application of 10 kg sulfur (S)/ha as ammonium sulfate, and 1 kg zinc (Zn) (as zinc chelate) were made into the fertiliser trench. Every deep P plot received the equivalent of 60 kg nitrogen (N)/ha. There were five replicates.

Field crop history*:

- wheat in 2013
- chickpea in 2014
- wheat in 2015

Above ground biomass was collected at hard-dough stage (12 October 2015) and analysed for nutrient content via acid digestion and ICP (inductively coupled plasma) determination. Treatments sampled were FR, 0P and 20P both with and without starter, and 60P with starter. Grain samples collected at harvest were ground and sent for chemical analysis also.

Grain yield was measured using a plot harvester on 18 November 2015, and grain yield corrected to receival moisture of 12.5%.

P uptake in above ground dry matter (kg/ha) was calculated as the above ground dry matter (kg/ha) x P concentration (%), while grain P removed (kg/ha) was calculated as moisture corrected grain yield (kg/ha) x P concentration (%).

Results

Two machines were used to sow the trial – one machine used to sow the -Starter runs and the other machine on the +Starter. Unfortunately establishment was poorer on one machine than

*Note: only 2015 data is presented. A complete summary of all years' data is currently being compiled.

the other compromising our ability to compare the starter fertiliser treatments.

Yields responses to increasing the rate of deep P application were inconsistent making interpretation of the results problematic (Figure 1). Grain yield of treatments FR, 0P, 20P and 80P are the same, while those of 5P, 10P and 40P are higher. If the P response is consistent, then the 20P and 80P should be similar to 40P.

Dry matter growth at maturity was indicating more consistent effect of deep P, with increasing growth relating to increasing rate (Figure 2). There appeared some effect of either deep tillage and/or basal nutrient with a slight increase in the 0P treatment compared to the unripped FR.

Crop P uptake was significantly higher in the 80P treatment (19.56 kg/ha) than all the remaining treatments (FR 14.58 kg/ha, 0P 15.96 kg/ha and 20P 16.56 kg/ha). Grain P removal was only significantly different with FR treatment (11.18 kg/ha) lower than the remaining treatments (0P was 12.33 kg/ha, 20P was 12.53 kg/ha and 80P was 12.84 kg/ha).

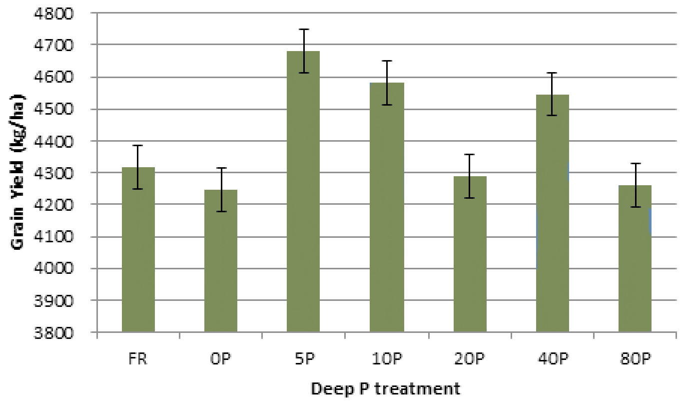

Figure 1. Grain yield for deep placed phosphorus treatments at Lundavra in 2015

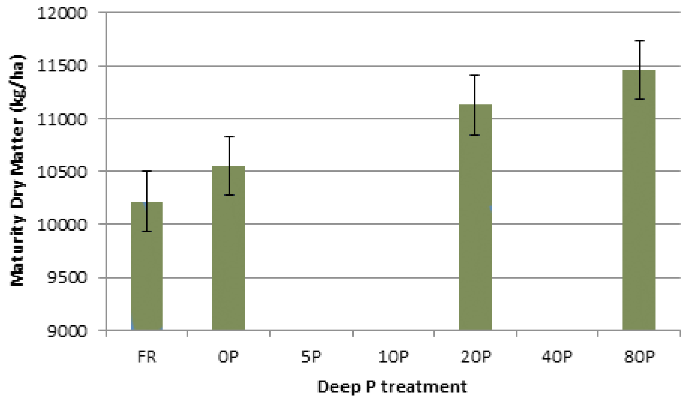

Figure 2. Maturity dry matter averaged over starter treatment for selected deep phosphorus treatments at Lundavra in 2015

Implications for growers

While dry matter and crop P uptake was increased with increasing rate of P applied at depth, there was no consistent impact on grain yield. There were several good rainfalls early in the growing season, but after the end of July individual rainfalls were small. Growers are advised to continue using starter application.

Wheat 2015

Acknowledgements

The hosting of the site by the co-operators is greatly appreciated. This work is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ00063 'Regional soil testing guidelines for the northern grains region'.

Trial details

Location:	Lundavra
Crop:	Sunguard[⊕] wheat sown on 13 May 2015 at 50 kg/ha using 33 cm row spacing
Fertiliser:	Starter Zn at 20-25 kg/ha in the seed row at sowing
Soil type:	Brown vertosol (Belah Brigalow)
In-crop rainfall:	140 mm

Selected soil fertility characteristics for Lundavra trial site:

Depth	Col P	BSES P	Ex K	ECEC
0-10 cm	25	83	1.14	26
10-30 cm	4	18	0.48	32

Wheat yield maintained with starter and increased with deep phosphorus – Condamine

Dr David Lester[1] and Prof Michael Bell[2]
1 Department of Agriculture and Fisheries
2 University of Queensland

Research Questions: *Does putting phosphorus (an immobile nutrient) in the soil at 15-20 cm deep increase grain yields on the Western Downs? | How does starter phosphorus interact with deep placed phosphorus?*

Key findings

1. Starter fertiliser supports higher grain yield and growers are encouraged to continue using it
2. A combination of deep placed phosphorus, basal nutrients and tillage gave an increased grain yield in the second crop after application. Yield increase with basal nutrient and tillage was 341 kg/ha and with additional deep phosphorus the increase was 290 kg/ha – a combined gain of 16%

Background

As the length of time we have been cropping land increases, immobile nutrients such as phosphorus (P) and potassium (K) are being taken up and removed by plants from the soil in the 10-30 cm layer. Application of starter fertiliser and return of crop residue to the soil surface is depositing these nutrients into this layer. This is creating a stratified distribution of higher nutrient availability in the surface and lower availability below. Root activity in the soil surface can be limited through faster loss of soil moisture, while deeper soil layers can offer longer periods of root activity as they are not as prone to evaporative moisture loss.

This research is questioning if placing immobile nutrients into the soil between 15-20 cm deep can increase grain yield.

Treatments

Treatments were established in December 2013.

1. farmer reference - untreated control (representative of district production practice) (FR)
2. deep ripped only (0P)
3. 10 kg P/ha (10P)
4. 20 kg P/ha (20P)
5. 30 kg P/ha (30P)
6. 60 kg P/ha (60P)

Each deep P rate was split into two plots: one without starter (-Starter) and an adjacent plot with starter applied (+Starter) as the grower normally would.

Deep placement was between 15 and 20 cm deep with bands spaced 50 cm apart. The additional P was applied as mono-ammonium P (MAP) (10% N, 22% P). Bands are perpendicular to the sowing row. Additional basal application of 10 kg sulfur (S)/ha as ammonium sulfate, and 0.5 kg zinc (Zn) (as zinc oxide) were made into the fertiliser trench. Every deep P plot received the equivalent of 60 kg nitrogen (N)/ha. There were six replicates.

Field cropping history

- chickpeas in 2014
- wheat in 2015

An early NVT wheat site was planted over several deep P experiment plots resulting in two replicates becoming removed from the analysis for this season. The impact for future crops of those (NVT) trial areas will require consideration.

Above ground biomass was collected on 25 September and analysed for nutrient content via acid digestion and ICP (inductively coupled plasma) determination. Treatments sampled were FR, 0P and 20P both with and without starter, and 60P with starter. Grain samples collected at harvest were ground and sent for chemical analysis also.

Grain yield was measured using a plot harvester on 21 October 2015, and grain yield corrected to receival moisture of 12.5%.

*Note: only 2015 data is presented. A complete summary of all years' data is currently being compiled.

P uptake in above ground dry matter (kg/ha) was calculated as the above ground dry matter (kg/ha) x P concentration (%), while grain P removed (kg/ha) was calculated as moisture corrected grain yield (kg/ha) x P concentration (%).

Results

Dry matter at maturity was not significantly influenced by any treatment (data not shown). FR and 0P dry matter was equivalent with around 9850 kg/ha produced, 20P was 10,695 kg/ha and 60P 11,050 kg/ha. Similarly as dry matter was not affected by treatment, neither was uptake of P. Mean uptake for the deep treatments was 9.88, 10.19 and 11.68 kg P/ha for the FR, 0P and 20P treatments respectively.

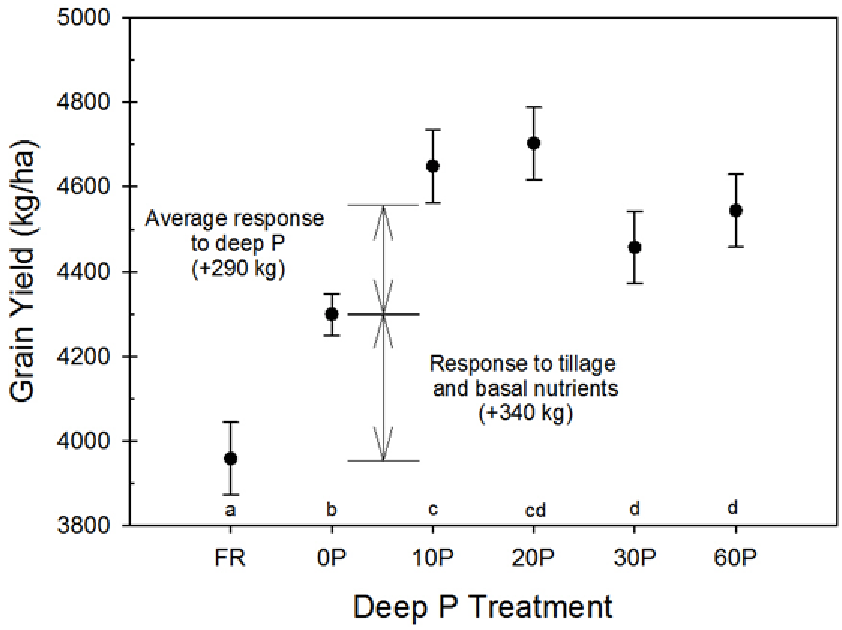

Figure 1. Grain yield of deep phosphorus treatments in wheat at Condamine in 2015

Grain yield was influenced by starter application separately from the deep treatment. In considering the main effects, not using starter decreased the average grain yield by 94 kg/ha (2.1%). For the deep treatments, the difference between the FR treatment and 0P was significantly different suggesting a residual effect of either the deep tillage to apply the treatments and/or the basal N, S or Zn applied (Figure 1). For the combined tillage + basal fertiliser treatment, grain yield increase was 341 kg/ha (8.6%).

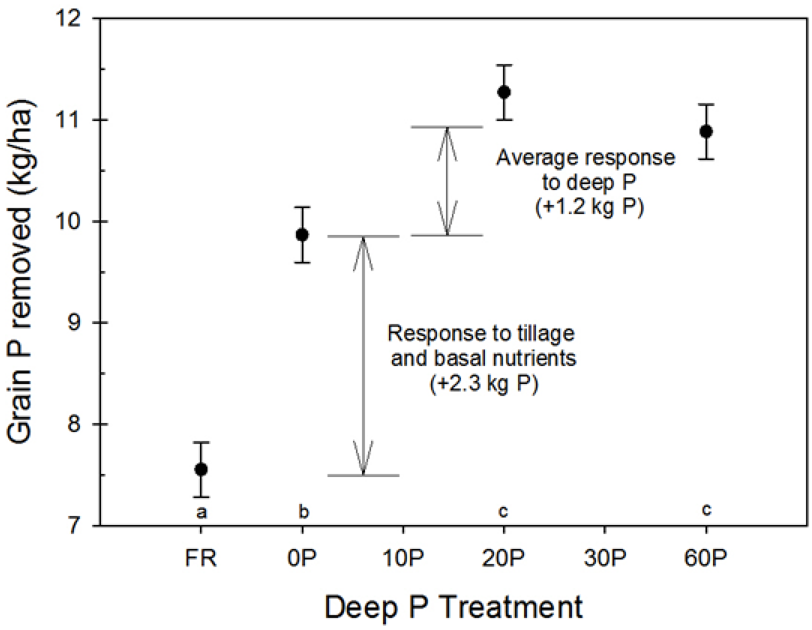

Figure 2. Grain phosphorus removed in wheat at Condamine in 2015

Deep P treatment significantly increased grain yield further with the average increase across all P rates being 290 kg/ha (Figure 1). While there are differences between the deep P treatments (10 and 20 vs 30 and 60) the reduced replication at the site reduces confidence in the measured effect being substantial.

Phosphorus removal in grain (like yield) significantly increased as grain yield increased with deep P treatment.

Mean grain P removal with the FR treatment was 7.48 kg P/ha, this increased with the 0P response (from tillage + basal fertiliser) to 9.77 kg P/ha. Notably while the grain yield increase was only 290 kg/ha the grain P removal increase was 2.29 kg P/ha (or 30% higher) - despite having no extra P applied. One possibility is that the tillage (in the previous year) has made it easier for root exploration by the crop compared to the untilled FR. Mean removal from the 20P and 60P treatments was significantly higher again, with another 1.2 kg P/ha higher again than the 0P.

Implications for growers

Wheat yields at this site in this season have been supported through use of a starter fertiliser, or increased from a combination use of deep placed P and additional basal nutrients + tillage. While the response to treatments is encouraging, further assessment over the medium term is suggested to develop a better understanding of size and frequency of crop responses with a range of growing seasonal conditions.

Growers are advised to continue their current practice of applying starter fertilisers.

Overall dry matter P uptake was very similar to that removed in grain suggesting that most of what the crop takes up is removed.

Acknowledgements

The hosting of the site by the co-operators is greatly appreciated. This work is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ00063 'Regional soil testing guidelines for the northern grains region'.

Trial details

Location:	Condamine
Crop:	Suntop(PBR) wheat sown on 13 May 2015 at 44.5 kg/ha using 33 cm row spacing.
Fertiliser:	DAP at 22 kg/ha in the seed row at sowing
Soil type:	Grey vertosol (Belah Brigalow)
In-crop rainfall:	137mm

Selected soil fertility characteristics for Condamine trial site:

Depth	Col P	BSES P	Ex K	ECEC
0-10 cm	13	25	0.68	20
10-30 cm	4	6	0.28	24
30-60 cm	3	5	0.22	25

Deep phosphorus application

2015 trial

Sulfur fertiliser increased double crop barley yield - Irongate

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1 Department of Agriculture and Fisheries
2 University of Queensland

Research Question: *Is sulfur limiting grain yields on the Darling Downs?*

Key findings

1. Grain yield increased as crop sulfur uptake increased
2. Increasing sulfur fertiliser rate increased dry matter sulfur uptake under double cropping

Background

Organic matter has declined in soils as cropping continues. This has resulted in a loss of organic nitrogen (N) and sulfur (S) from the soil nutrient pool. Sulfur availability from the organic pool is similar to N with increased plant availability following an opportunity for the soil to mineralise and release sulfur. Inorganic sulfur can be present in higher concentrations down the soil profile, but roots have to be able to access that to be recoverable. Periods of high cropping intensity, when mineralisation is very low or roots unable to extract deeper S, crop responses to shallow fertiliser S may be more likely.

Treatments

Treatments were established in September 2014.

Experimental treatments include;

1. 0 kg S/ha (0S) (2 per replicate)
2. 5 kg S/ha (5S)
3. 10 kg S/ha (10S)
4. 20 kg S/ha (20S)
5. 40 kg S/ha (40S)

Sulfur was applied as ammonium sulfate (21% N 24% S). Nitrogen as urea was applied to balance nitrogen to 120 kg N/ha with the original application. There were six replicates.

Field cropping history*:

- sorghum in the spring of 2014-15
- double cropped to barley in May 2015.

Above ground biomass was collected on 23 October 2015 and analysed for N using Leco combustion method and nutrient content via acid digestion and ICP (inductively coupled plasma) determination.

All treatments were sampled except the 5S treatment. Grain samples collected at harvest were ground and sent for the same chemical analysis.

Grain yield was measured using a plot harvester on 24 October 2015, and grain yield corrected to receival moisture of 12.5%.

S uptake in above ground dry matter (kg/ha) was calculated as the above ground dry matter (kg/ha) x S concentration (%). Grain S removed (kg/ha) was calculated as moisture corrected grain yield (kg/ha) x S concentration (%).

*Note: only 2015 data is presented. A complete summary of all years' data is currently being compiled.

Results

Above ground dry matter (kg/ha) was not influenced by S application (Table 1), but S concentration in dry matter ($p<0.001$) and S uptake in dry matter ($p<0.001$) where both significantly increased with increasing rate of S application.

Table 1. Dry matter, sulfur concentration and uptake in barley at Irongate in 2015

S rate (kg S/ha)	0	10	20	40
DM (kg/ha)	11690	11439	11777	12280
DM S con (mg/kg)	867 a	983 a	1167 b	1317 c
DM S up (kg/ha)	10.06 a	11.63 a	13.80 b	16.37 c

Numbers with the same letter behind are not statistically different at the 5% level

The effect of S rate on grain yield was approaching significance ($p=0.078$), but an alternate way to consider the effect is plotting dry matter S uptake against grain yield (Figure 1). Maximum yield (5950 kg/ha) was achieved

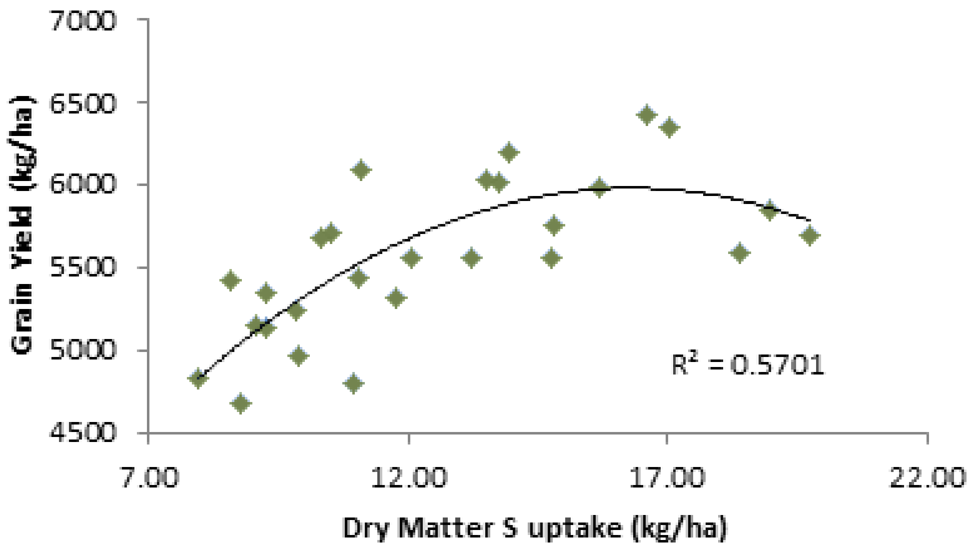

Figure 1. Dry matter sulfur uptake at maturity vs grain yield in barley at Irongate in 2015

at uptake of 15 kg S/ha which was roughly the amount in the crop from the 20S treatment (Table 1). Grain yield at S uptake of 10 kg/ha was 5320 kg/ha, a reduction of 630 kg/ha in yield.

Grain S concentrations while statistically significantly different, show little actual variation in concentration (data not shown). Grain N:S ratio also did not discriminate between responsive and non-responsive treatments.

Implications for growers

Where growers are double-cropping into high yielding summer cereal fields, consider applying sulfate-S at 15-20 kg S/ha. Most of the applied S appears to be retained in the field as S removal in grain has not increased at the same rate as yield (Table 2).

Table 2. Sulfur removal in barley grain at Irongate in 2015

S rate (kg S/ha)	0	10	20	40
Grain S up (kg/ha)	5.81 a	6.45 ab	6.59 b	6.75 b

Numbers with the same letter behind are not statistically different at the 5% level

Acknowledgements

The hosting of the site by the co-operators is greatly appreciated.

This work is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ00063 ‘Regional soil testing guidelines for the northern grains region’.

Trial details

Location: Irongate

Crop: Compass⊕ barley sown on 23 May 2015 at 55 kg/ha using 37 cm row spacing.

Fertiliser: Yara 13Z at 20 L/ha in the seed row at sowing

Soil type: Black vertosol (Waco)

In-crop rainfall: 82 mm

Selected soil fertility characteristics for Irongate trial site

Depth	Col P	BSES P	Ex K	ECEC	MCP-S
0-10 cm	52	164	2.05	65	5
10-30 cm	12	210	0.88	68	2.6
30-60 cm	4	210	00.83	67	3.1

Barley 2015

Chickpea yield not affected with deep phosphorus or potassium - Jimbour

Dr David Lester[1] and Prof Michael Bell[2]
1 Department of Agriculture and Fisheries
2 University of Queensland

Research Question: *On stratified soils, does applying potassium at 15-20 cm deep in the soil, either with our without phosphorus increase grain yields?*

Key findings

1. Deep potassium either with or without deep phosphorus had no impact on chickpea crop growth, nutrient uptake of potassium or phosphorus, or grain yield

Background

Immobile nutrients such as potassium (K) and phosphorus (P) are retrieved by plants from the soil in the 10-30 cm layer. Traditionally, application of starter fertilisers and return of crop residue to the soil surface is depositing these nutrients onto the upper soil layer, creating a stratified distribution of higher availability in the surface and lower availability below. Root activity in the soil surface can be limited through faster loss of soil moisture, while deeper soil layers can offer longer periods of root activity as they are not as subject to evaporative moisture loss.

This research is questioning if placing immobile nutrients into the soil between 15-20 cm deep can increase grain yield.

Treatments

This trial was established in 2013 with the following treatments:

1. Farmer reference - Untreated control (representative of district production practice) (FR)
2. 0 kg K/ha plus 20 kg P/ha (0K20P)
3. 25 kg K/ha plus 20 kg P/ha (25K20P)
4. 50 kg K/ha plus 20 kg P/ha (50K20P)
5. 100 kg K/ha plus 20 kg P/ha (100K20P)
6. 0 kg K/ha deep ripped without P (0K0P)
7. 100 kg K/ha deep ripped without P (allowing exploration of the interaction between K and P in the soil). (100K)

K was applied as potassium chloride (KCl), and P as mono-ammonium phosphate (MAP). Deep placement was between 15-20 cm deep with bands spaced 50 cm apart. Bands were perpendicular to the sowing row. Additional basal application of 20 kg sulfur (S)/ha as ammonium thiosulfate, and 2 kg zinc (Zn) (as zinc sulfate) were made into the fertiliser trench. Urea was applied to balance nitrogen (N) application in deep treatments to 40 kg N/ha. There were six replicates.

Field cropping history*:

- dryland cotton in 2013-14
- sorghum in 2014-15.

Five treatments were sampled for above ground biomass prior to defoliation on 8 October 2015: FR, 0 and 100K, both with and without P. These were analysed for nutrient content via acid digestion and ICP (inductively coupled plasma) determination. Grain samples collected at harvest were ground and sent for chemical analysis also.

Grain yield was measured using a plot harvester on 5 November 2015, and grain yield corrected to receival moisture of 12.5%.

PKS uptake in above ground dry matter (kg/ha) was calculated as the above ground dry matter (kg/ha) x concentration (%), while grain nutrient removed (kg/ha) was calculated as moisture corrected grain yield (kg/ha) x concentration (%).

Results

Dry matter at maturity was not influenced by any treatment (trial mean 7840 kg/ha). Nutrient concentration in whole plants of P or K was also not influenced by any treatment (mean P concentration 1700 mg/kg, mean K 1.62%).

While none of the treatments increased grain yield specifically, yield increased in the experiment by the combination of deep tillage and basal nutrient application (N, S or Zn) –

*Note: only 2015 data is presented. A complete summary of all years' data is currently being compiled.

Table 1. Grain yield and nutrient concentrations for chickpea at Jimbour West in 2015

Treatment	Significance	FR	0K 0P	0K 20P	25K 20P	50K 20P	100K 0P	100K 20P
Grain Yield (kg/ha)	0.035	1870 a	1977 b	2040 b	2003 b	2008 b	1992 b	2066 b
Grain P (mg/kg)	NS	3683	3667	3725			3500	3733
Grain K (%)	NS	1.06	1.05	1.05			1.02	1.05
Grain S (mg/kg)	NS	1850	1933	1917			1900	1933
Grain Zn (mg/kg)	NS	43.7	44.5	44.3			43.6	44.5

Numbers with the same letter behind are not statistically different at the 5% level

although what the influence is remains uncertain (Table 1). Average yield across the 'deep' treatments is 2014 kg/ha. This is an increase over the untreated FR plots of 144 kg/ha, about a 7.5% yield increase.

Analysis of the grain P, K, S and Zn concentration shows no significance differences between any treatments (Table 1) suggesting none of them are related to the yield response.

Implications for growers

While chickpea prices were high in 2015 ($800/t), this yield response represents approximately $110/ha. However, identifying the mechanism that was responsible is difficult – with grain chemical analysis unable to provide any likely suggestion. It may be;

- Residual N response
- Deep tillage response

Acknowledgements

The hosting of the site by the co-operators is greatly appreciated.

This work is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ00063 'Regional soil testing guidelines for the northern grains region'.

Trial details

Location:	Jimbour West
Crop:	Chickpea PBR HatTrick⦶ sown on 3 June 2015 at 55 kg/ha using 37.5 cm row spacing
Fertiliser:	Granulock Z® at 30 kg/ha
Soil type:	Grey vertosol
In-crop rainfall:	105 mm

Selected soil fertility measures at Jimbour West deep K+/- P trial site.

Depth	Col P	BSES P	Ex K	ECEC
0-10 cm	32	35	0.84	41
10-30 cm	7	14	0.40	45

Chickpea 2015

Does rate and row spacing of deep phosphorus and potassium affect crop response? – Jimbour

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1 Department of Agriculture and Fisheries

2 University of Queensland

Research Question: *When deep placing phosphorus or potassium, is how much you apply; where you apply it; or both changing how crops respond?*

Key findings

1. Early season phosphorus responses were impressive – 12% increase with tillage and basal and another 12% with 40 kg P/ha
2. Dry conditions reduced grain yield responses. Deep-placed phosphorus at greater than 20 kg/ha increased yields slightly (≈260 kg/ha). Deep placed potassium had no effect
3. Difficult to resolve row spacing effects overall

Background

Yields are being reliably increased with deep placed phosphorus (P) or potassium (K) for grain crops, but questions on what the combination of fertiliser row spacing and application rates are emerging. Recent fertiliser rate response experiments have used a fertiliser band spacing of 50 cm. Earlier exploratory placement experiments suggested 25 cm bands are equivalent to 50 cm bands and both were better than 100 cm bands. These experiments used a constant rate of application, so different spacings were also characterised by different in-band nutrient concentrations – a key determinant of the rate of diffusive supply to crop roots. Grass crop species (wheat, barley, sorghum) with fibrous root systems have been able to utilise 50 cm bands, whilst coarsely rooted pulse crops have been shown to not be as reliable at utilising deep-placed P and K bands. This research is attempting to assess how different fertiliser rates at different row spacing combinations alter crop response and fertiliser recovery, hopefully over a range of crop species with contrasting rooting characteristics.

Treatments

Two experiments were established on 16-18 March 2015, each one comparing three row spacings (25, 50 and 100 cm) for different P (Table 1) and K (Table 2) rates. Experimental treatments include an untreated control (FR) left as representative of district production practice.

Mono-ammonium phosphate (MAP 10N 22P) was used as the P source for experiment 1, with liquid potassium sulfate (KTS 30K 25S) and zinc sulfate (17 Zn) applied as basal nutrients. For experiment two, muriate of potash (potassium chloride) (50 K) was used as the K fertiliser, with liquid MAP (10 N 15P) and zinc (Zn) sulfate (17 Zn) applied as basal nutrients. There were six replicates in each experiment.

Table 1. Treatment details for phosphorus rate x row spacing experiment

Treatment	P rate (kg/ha)	Row spacing (cm)	Deep tillage (Y/N)	Basal nutrient rate
Ctrl P (25)	0	25	Y	50 K, 42 S, 2 Zn
Ctrl P (50)	0	50	Y	50 K, 42 S, 2 Zn
Ctrl P (100)	0	100	Y	50 K, 42 S, 2 Zn
10 P (25)	10	25	Y	50 K, 42 S, 2 Zn
10 P (50)	10	50	Y	50 K, 42 S, 2 Zn
20 P (100)	20	25	Y	50 K, 42 S, 2 Zn
20 P (25)	20	50	Y	50 K, 42 S, 2 Zn
20 P (50)	20	100	Y	50 K, 42 S, 2 Zn
40 P (100)	40	25	Y	50 K, 42 S, 2 Zn
40 P (25)	40	50	Y	50 K, 42 S, 2 Zn
40 P (50)	40	100	Y	50 K, 42 S, 2 Zn
80 P (100)	80	100	Y	50 K, 42 S, 2 Zn
FR (25)	-	25	N	0
FR (50)	-	50	N	0
FR (100)	-	100	N	0

Table 2. Treatment details for potassium rate x row spacing experiment

Treatment	K rate (kg/ha)	Row spacing (cm)	Deep tillage (Y/N)	Basal nutrient rate
Ctrl K (25)	0	25	Y	20 P, 10 S, 2 Zn
Ctrl K (50)	0	50	Y	20 P, 10 S, 2 Zn
Ctrl K (100)	0	100	Y	20 P, 10 S, 2 Zn
25 K (25)	25	25	Y	20 P, 10 S, 2 Zn
25 K (50)	25	50	Y	20 P, 10 S, 2 Zn
25 K (100)	25	100	Y	20 P, 10 S, 2 Zn
50 K (25)	50	25	Y	20 P, 10 S, 2 Zn
50 K (50)	50	50	Y	20 P, 10 S, 2 Zn
50 K (100)	50	100	Y	20 P, 10 S, 2 Zn
100 K (25)	100	25	Y	20 P, 10 S, 2 Zn
100 K (50)	100	50	Y	20 P, 10 S, 2 Zn
100 K (100)	100	100	Y	20 P, 10 S, 2 Zn
FR (25)	-	25	N	0
FR (50)	-	50	N	0
FR (1.00)	-	100	N	0

Figure 1. Trial site on a) 18 March following treatment application and b) 27 March after 50 mm rainfall

Early visual responses in the P experiment where encouraging and subsequently on 12 August 2015 a biomass cut was taken from treatments 2, 5, 8, 11 and 14 - representing all P rates at the 50 cm spacing. Maturity samples were collected from all plots on 22 September 2015. Samples were analysed for nutrient content via acid digestion and ICP (inductively coupled plasma) determination.

Grain yield was measured using a plot harvester on 23 October 2015, and grain yield corrected to receival moisture of 12.5%. Grain samples collected at harvest were ground and sent for chemical analysis also.

P or K uptake in above ground dry matter (kg/ha) was calculated as the above ground dry matter (kg/ha) x concentration (%), while grain nutrient removed (kg/ha) was calculated as moisture corrected grain yield (kg/ha) x concentration (%).

Results

Early growth responses showed increased growth with deep placed P in both experiments (Figure 2).

Figure 2. Growth responses in treated (top and bottom) and untreated (centre) deep placed phosphorus plots in barley on 7 August 2015

Dry matter cuts taken shortly after Figure 2 show an initial response to the combination of tillage and basal nutrients (a 13% increase in the Ctrl P compared to FR, which is untreated). In addition to this, increasing P application rates further increased crop growth (Table 3).

Table 3. Early dry matter for selected phosphorus rates at 50 cm row spacing in barley 12 August 2015

Trt	FR (50 cm)	Ctrl P (50 cm)	10P (50 cm)	20P (50 cm)	40P (50 cm)
DM (kg/ha)	4753	5486	5750	5944	6353
% response in comparison to FR		13	17	20	25

Following this early response, and despite 46.5 mm rain received over a five-day period in late August the potential to substantially increase grain yield was not realised. A relatively warm spring with higher temperatures through September and October would have increased crop water use, while the late August rainfall may have provided some access to (previously dry) surface soil layers with reasonable P and K fertility.

Yield increases of 200 to 300 kg/ha were measured in the P rate x row spacing experiment with application rates of 20 kg P/ha and greater (Figure 3), whilst no row spacing differences were detected.

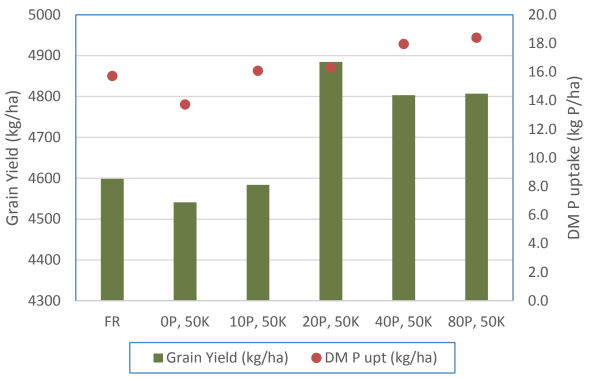


Figure 3. Grain yield averaged over row spacing for phosphorus application rates in the phosphorus rate x row spacing experiment for barley in 2015

In the K rate x row spacing experiment, neither rate or row spacing had any effect on grain yield (Figure 4) while the basal P application of 20 kg P/ha did increase yield by roughly similar amounts to that measured in the P rate x row spacing experiment adjacent. Potassium uptake similarly was increased with basal P application but not largely by the K fertiliser rates; however the recovery of K by the crop is being evaluated through the use of a rubidium tracer technique that has been able to differentiate fertiliser and background plant K uptake at other sites.

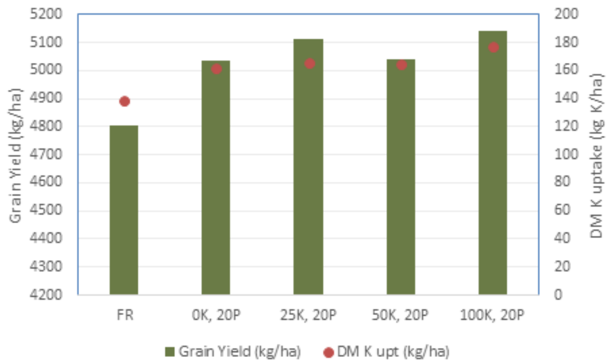


Figure 4. Grain yield response averaged over row spacing for K application rates in the K rate x row spacing experiment for barley in 2015

Implications for growers

Deep placed P has only slightly increased grain yield, while K application has not appeared to give any grain yield response in this crop.

The site is currently being fallowed through for sorghum in 2016-17 and will be monitored then.

Acknowledgements

The hosting of the site by the co-operators is greatly appreciated.

This work is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ00078 'Deep placement of nutrients'.

Trial details

Location:	Jimbour West
Crop:	Shepherd⁽ᶦ⁾ barley sown on 21 May 2015 at 50 kg/ha using 37.5 cm row spacing
Fertiliser:	Big N ® at 100 kg/ha and Granulock Z® at 30 kg/ha
Soil type:	Grey vertosol
Rainfall:	105 mm

Selected soil fertility measures at Jimbour West deep K+/- P trial site:

Depth	Col P	BSES P	Ex K	ECEC
0-10 cm	27	58	0.53	35
10-30 cm	4	18	0.18	33
30-60 cm	4	17	0.19	41

Does the combined application of nitrogen, phosphorus and potassium impact crop recovery? – Jimbour

Dr David Lester[1] and Prof Michael Bell[2]
1 Department of Agriculture and Fisheries
2 University of Queensland

Research Question: *When multiple nutrient constraints are present can you apply nitrogen, phosphorus and potassium fertilisers together in the one band without limiting crop utilisation?*

Key findings

1. No effect on grain yield, small benefit in biomass at maturity
2. No obvious negative effects on crop uptake from first year's data

Background

Occasionally in previous experiments with nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) nutrient additions, there was a suggestion of possible negative effects from applying multiple fertilisers into one band in the soil. One possible mechanism involved in the response reduction to the applied nutrients was the in-situ formation of insoluble KP reaction products where high rates of ammonium are applied in the band with soluble P and K. Urea, mono-ammonium phosphate (MAP) and muriate of potash (potassium chloride (KCl)) are the most commonly used granular fertilisers for N, P and K in Australia due to the low cost per nutrient and ease of handling. This research is attempting to assess how applying product combinations alters crop recovery of applied P and K.

Treatments

An experiment was established on 17 March 2015 comparing applying urea, MAP and KCl in various additive product combinations (Table 1). Target application rate was 60 kg N/ha, 40 kg P/ha and 100 kg K/ha. A control treatment with N only was included to establish baseline P and K recovery. Fertilisers applied 'together' were on 50 cm bands, whilst the 'away' fertiliser was placed mid-distance between these rows. A basal application of zinc (Zn) sulfate (17 Zn) at 2 kg Zn/ha was made to all plots. The experiment had six replicates.

Table 1. Treatment details for fertiliser placement

Treatment	Product(s)	Product rate (kg/ha)	Placed together	Placed away
Control	Urea	60N	-	-
Ur+MAP+KCl	Urea, MAP, KCl	60N 40P 100K	All	-
MAP+KCl/Ur	Urea, MAP, KCl	60N 40P 100K	MAP + KCl	Urea
Ur+MAP/KCl	Urea, MAP, KCl	60N 40P 100K	Urea + MAP	KCl
Ur+KCl/MAP	Urea, MAP, KCl	60N 40P 100K	Urea + KCl	MAP

Maturity samples were collected from all plots on 22 September 2015. Samples were analysed for nutrient content via acid digestion and ICP (inductively coupled plasma) determination.

Grain yield was measured using a plot harvester on 23 October 2015, and grain yield corrected to receival moisture of 12.5%. Grain samples collected at harvest were ground and sent for chemical analysis also.

P or K uptake in above ground dry matter (kg/ha) was calculated as the above ground dry matter (kg/ha) x concentration (%), while grain nutrient removed (kg/ha) was calculated as moisture corrected grain yield (kg/ha) x concentration (%).

Results

Statistically the maturity dry matter (kg/ha) was increased with P and K application compared to the control (p=0.05), but there were no differences between any of the PK placements (Table 2). Pragmatically the responses are relatively small (couple of hundred kg). Applying the P and K made the difference; not where or what you put it with in terms of crop growth for this season.

Table 2. Mean values of maturity dry matter, phosphorus and potassium uptake and grain yield for fertiliser placement combinations at Jimbour West with barley in 2015. Numbers with the same letter are not significantly different at 5% level

	DM (kg/ha)	DM P uptake	DM K uptake	Grain Yield
Control	11900a	16.74a	131.5a	4726a
Ur+MAP+KCl	12795b	21.41b	156.0b	4731a
MAP+KCl/Ur	12048b	18.68b	140.8b	4944a
Ur+MAP/KCl	12111b	19.28b	122.8a	4856a
Ur+KCl/MAP	12568b	18.20b	154.6b	4800a

Grain yield was not affected by any treatment (p>0.05).

Statistically, there are differences in P uptake (Table 2) between the control and treated (PK added) plots (p=0.01) but similarly to the dry matter response, no difference exists between PK placements. With K uptake, differences between placement strategies were significant (p=0.01) with the K placed away from N and P (Ur+MAP/KCl) having a lower uptake than other treatments where K was placed with N and/or P.

Further investigation into the sources of variation in measuring crop nutrient uptake will be undertaken to offer pathways to improved measurement precision in future.

Implications for growers

While some growth differences were measured in maturity biomass, no effect on grain yield was established. After only one years experimentation, further study is needed to improve understanding on placing multiple fertiliser products in the one band.

The site is currently being fallowed through for sorghum in 2016-17 and will be monitored then.

Acknowledgements

The hosting of the site by the co-operators is greatly appreciated.

This work is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ00078 'Deep placement of nutrients'.

Trial details

Location:	Jimbour West
Crop:	Shepherd[Φ] Barley sown on 21 May 2015 at 50 kg/ha using 37.5 cm row spacing
Fertiliser:	Big N® at 100 kg/ha and Granulock Z® at 30 kg/ha
Soil type:	Grey vertosol

Selected soil fertility measures at Jimbour West deep K+/- P trial site:

Depth	Col P	BSES P	Ex K	ECEC
0-10 cm	27	58	0.53	35
10-30 cm	4	18	0.18	33
30-60 cm	4	17	0.19	41

Barley 2015

Does the use of different phosphorus fertilisers change crop response? – Jimbour

Dr David Lester[1] and Prof Michael Bell[2]
1 Department of Agriculture and Fisheries
2 University of Queensland

Research Question: *If you are applying deep-placed phosphorus, does it matter which granular product you use?*

Key findings

1. No effect on grain yield, small benefit in biomass at maturity
2. No obvious negative effects on crop uptake from first year's data

Background

There are three main fertiliser options in the deep application of phosphorus (P); triple super phosphate (TSP), mono-ammonium phosphate (MAP) and di-ammonium phosphate (DAP). Theoretically, these fertilisers can influence the soil around them due to their individual chemical characteristics. For example, they have different pH effects (TSP pH 3.5 vs DAP pH 8.5), but in practice does it make a difference in crop performance?

Treatments

An experiment was established on 17 March 2015 comparing applying TSP, MAP and DAP and if the different products impact on grain yield and crop P uptake. The three products were applied with urea and muriate of potash (potassium chloride (KCl)) with target application rates of 60 kg N/ha for nitrogen (N), 40 kg P/ha for P and 100 kg K/ha for potassium (K). A control treatment with N only was included to establish baseline P and K recovery. One set of treatments had products applied 'together' into the one fertiliser band, whilst another had urea fertiliser placed 'away' (mid-distance between these rows). Zinc (Zn) sulfate (17 Zn) was applied as a basal nutrient at 2 kg Zn/ha.

Table 1. Treatment details for phosphorus fertiliser comparison at Jimbour West

Treatment	Product(s)	Rate of products (kg/ha)	Placed together	Placed away
Ctrl	Urea	60N	-	-
Ur+TSP+KCl	Urea, TSP, KCl	60N 40P 100K	All	-
Ur+MAP+KCl	Urea, MAP, KCl	60N 40P 100K	All	-
Ur+DAP+KCl	Urea, DAP, KCl	60N 40P 100K	All	-
Ur/TSP+KCl	Urea, TSP, KCl	60N 40P 100K	TSP + KCl	Urea
Ur/MAP+KCl	Urea, MAP, KCl	60N 40P 100K	MAP + KCl	Urea
Ur/DAP+KCl	Urea, DAP, KCl	60N 40P 100K	DAP + KCl	Urea

Maturity samples were collected from all plots on 22 September 2015. Samples were analysed for nutrient content via acid digestion and ICP (inductively coupled plasma) determination.

Grain yield was measured using a plot harvester on 23 October 2015, and grain yield corrected to receival moisture of 12.5%. Grain samples collected at harvest were ground and sent for chemical analysis also.

P or K uptake in above ground dry matter (kg/ha) was calculated as the above ground dry matter (kg/ha) x concentration (%), while grain nutrient removed (kg/ha) was calculated as moisture corrected grain yield (kg/ha) x concentration (%).

Results

Statistically while there are some significant effects on maturity dry matter, P uptake in dry matter at maturity and grain yield (Table 2), however the differences are small.

Table 2. Mean values of maturity dry matter, phosphorus and potassium uptake, and grain yield

Treatment	DM (kg/ha)	DM P uptake	Grain yield
Ctrl	11879	16.72	4762
Ur+TSP+KCl	12646	17.06	4877
Ur+MAP+KCl	12477	21.28	4731
Ur+DAP+KCl	12772	18.74	4806
Ur/TSP+KCl	12415	18.74	4956
Ur/MAP+KCl	12048	18.36	4828
Ur/DAP+KCl	12072	17.04	4873

Further investigation into the likely advantages and disadvantages of the products on these soil types will refine the research process further.

Implications for growers

After only one years' experimentation, further study is needed to improve understanding on which P fertiliser product provides the best source for crop utilisation over the medium term.

The site is currently being fallowed through for sorghum in 2016-17 and will be monitored then.

Acknowledgements

The hosting of the site by the co-operators is greatly appreciated.

This work is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ00078 'Deep placement of nutrients'.

Trial details

Location: Jimbour West

Crop: Shepherd(p) barley sown on 21 May 2015 at 50 kg/ha using 37.5 cm row spacing

Fertiliser: Big N® at 100 kg/ha and Granulock Z® at 30 kg/ha

Soil type: Grey vertosol

Selected soil fertility measures at Jimbour West deep K+/- P trial site:

Depth	Col P	BSES P	Ex K	ECEC
0-10 cm	27	58	0.53	35
10-30 cm	4	18	0.18	33
30-60 cm	4	17	0.19	41

Barley 2015

Soils research

Work to date has been focused on soil organic matter. Soil organic matter is critical for healthy soils and sustainable agricultural production; however levels under cropping systems are continuing to decline over time. Growers are looking for practical and profitable ways to manage their soil organic matter and soil carbon into the future; hopefully to increase or at least maintain their soil organic carbon levels. Two projects were funded in 2012: one by the Grains Research and Development Corporation (GRDC); and the second was federally funded by Department of Agriculture, Fisheries and Forestry (DAFF).

Soil organic matter and soil carbon can seem confusing and very complicated; but the basic principles are really quite simple. These projects aim to cut through the complexity, mystery and misinformation around these topics and help growers develop scientifically sound and profitable carbon strategies for their own farms. Demonstration sites were set up to investigate the impact a range of farm management strategies have on soil organic carbon levels and an extensive on-farm soil testing program was undertaken, both of which were aimed at helping growers understand the functions of soil organic matter in grain production systems, and how current farming systems are affecting soil carbon levels.

The main findings across these projects to date include:

- Long-term cropping across the northern grains region continues to deplete soil organic carbon levels.
- The resulting declines in available nutrient reserves (typically nitrogen) leads to increased use of fertiliser, extra costs and the reduced profitability of grain cropping over time.
- These changes in soil carbon appear to be driven by the lengthy fallow periods in northern grain cropping systems.
- Productive pasture phases are the 'stand-out' option to improve total soil organic carbon levels in mixed farming systems.
- Soil phosphorus levels on many of the degraded long-term cropping soils are very low.

The demonstration sites at Warra, Brigalow and Chinchilla will continue to be monitored over the next year when they will be re-sampled and analysed.

Planting pasture

Slashed pasture plot

Increasing soil organic matter under cropping: manure versus fertiliser - Warra

Jayne Gentry, Dr David Lawrence and James Hagan
Department of Agriculture and Fisheries

Research Question: *What is the soil carbon benefit of using feedlot manure as compared to granular fertiliser within a dryland grain cropping system?*

Key findings

1. There were no statistically significant changes in soil organic carbon within this short time frame
2. The grain yield responded to the amount of nutrients rather than the source
3. The choice between manure and granular fertiliser should be on price, convenience or a preference for organic options

Background

Trial co-operators at Warra have been applying manure to their property on a 3 year rotational basis since 2002. The Improved Management of Soil Organic Matter for Profitable and Sustainable Cropping project team, in negotiation with the co-operator, designed and implemented a long term trial. This trial aimed to determine what the impact was of applying manure versus conventional fertiliser on the soil surface and deep in the soil profile on soil organic matter, yield and profitability.

Treatments

The current commercial treatment of 5 t/ha of stockpiled feedlot manure spread on the soil surface was varied to compare the impact of incorporating the manure, using a higher rate of manure, and comparing manure applications with traditional fertilisers to supply the same level of nutrients (determined by an analysis of the manure).

Treatments were (replicated three times):

- nil fertiliser
- 5 t/ha feedlot manure (surface applied, not incorporated) – commercial practice
- 5 t/ha feedlot manure (incorporated)
- 10 t/ha manure (surface applied, not incorporated)
- fertiliser rate equivalent to 5 t/ha manure (~342 CK55S kg/ha with seed as sowing)
- fertiliser rate equivalent to 10 t/ha manure (~685 CK55S kg/ha with seed as sowing)
- fertiliser rate equivalent to 5 t/ha manure (~342 CK55S kg/ha deep placement at ~20 cm)

All manure and fertiliser treatments were applied as one-off applications early 2013. The fertiliser rates were calculated following analysis of the manure at the site on a dry weight basis of 3.6 t/ha. The plots were all 1.6 km long and planted with commercial equipment to fit with normal farm practices. Sorghum was grown in 2013 and chickpea in 2014.

Results

Adding nutrients with manure or granular fertiliser increased sorghum grain yields ($P=0.05$) for all treatments, except the incorporated manure (5 t/ha). The only treatment that further increased yields above the existing commercial practice at the site (5 t/ha manure spread on the surface) was the deep placement of an equivalent amount of nutrients as fertiliser. The 'equivalent fertiliser' applied at normal depth with the seed produced the same result as the manure, indicating that the grain yield responded to the amount of nutrients and where they were placed, rather than the source. It appears that the dry season favoured this deep placement, which may have allowed the roots to access nutrients such as phosphorus, while the soil surface was too dry for root activity.

These treatment differences were similarly reflected in total dry matter measures which were only statistically significant again for the deep placement of fertiliser. Total dry matter is what drives changes in soil organic matter. However, the differences measured across these treatments from sorghum were all relatively small; less than 14% for dry matter in sorghum.

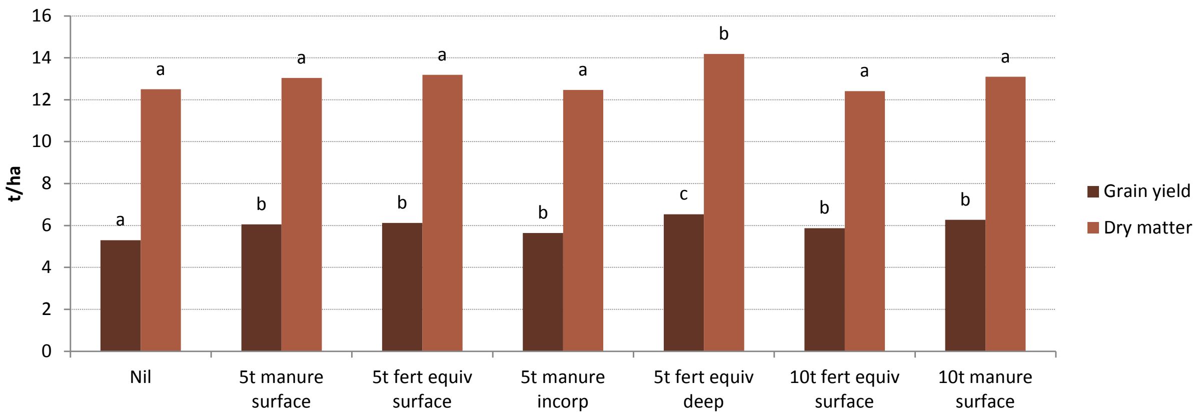


Figure 1. Sorghum 2013/14 grain yield and dry matter. Bars with the same letter are not significantly different at the 5% level.

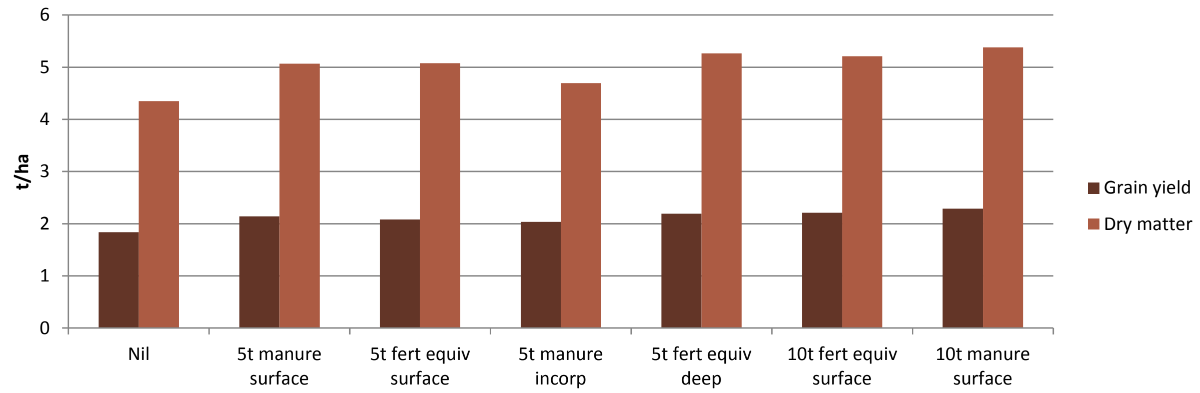


Figure 2. Chickpea 2014 grain yield and dry matter

The only statistically significant (P=0.05) result for chickpeas was a small grain response to the double rate of manure (10 t/ha). Consequently, with the minimal differences (if any) between treatments in the sorghum and chickpea crops. No significant soil organic carbon differences were expected from the re-sampling of paddocks after just two years in March 2015.

Total organic carbon levels under remnant vegetation on these brigalow soils in the Warra district are typically 3.0-3.5% for the 0-10cm layer. However, the mean total organic carbon levels on this soil were low (0.78%, Std error 0.0258 for 0-10 cm; 0.65%, Std error 0.0315 for 10-30 cm). Low levels are common where these soils have been cropped for 80-100 years. Despite a long cropping history, there had been no previous fertiliser applications on this site until the trial began.

This trial was planted to sorghum in 2015/16 summer season. It is planned that the fertiliser and manure treatments will be applied after this crop in keeping with the farmer's strategy. Total organic carbon will be re-sampled in 2017.

Return on investment (ROI) comparisons were made against the nil treatment versus the three manure treatments. They were not made against the fertiliser treatments as these were designed to mimic the nutrition available in the manure NOT to be an economically viable practice.

Assuming the following:

- sorghum price of $250/t (2013)
- chickpea price of $400/t (2014)
- 5t manure spread $50
- 5t manure incorporated $60
- 10t manure spread $100

5t manure applied at the surface proved the highest return on investment of 5.23 after two years.

Table 1. Return on Investment (after 2 years) for every dollar spent - Manure

Nil	5 t manure (surface)	5 t manure (incorp)	10 t manure (surface)
0	5.23	1.75	2.92

Table 2. Soil Organic Carbon stock (t/ha) in 0-30 cm (Bulk Density (BD) (0-10) =1.30; BD (10-30) = 1.52) at beginning of trial (2012) and 2015

	control	Manure 5 t/ha (surface)	Manure 10 t/ha (surface)	Manure 5 t/ha (incorp)	Fertiliser 5 t eqv (surface)	Fertiliser 10 t eqv (surface)	Fertiliser 5 t eqv (deep)
Start @ 2012	mean 31.65 t/ha (standard error 1.10)						
Interim @ 2015 (standard error)	35.06 (0.0280)	Not sampled	Not sampled	31.68 (1.001)	Not sampled	33.50 (2.138)	Not sampled

These results suggest that the existing grower practice of applying manure at 5 t/ha on the surface is currently best practice. All three manure treatments in this case provide returns of better than 100% within two years, which is heavily influenced by its low cost due to grower proximity to the source of manure.

While most farmers consider manure a better option for 'organic matter' as they expect it to boost soil organic carbon directly, our estimates of the nitrous oxide emissions suggest that it may be less desirable than inorganic fertilisers that have lower emissions when applied appropriately. The nitrous oxide emissions for the manure and fertiliser treatments were calculated from the analysis of the manure sample and the use of standard emission factors from the Australian National Greenhouse Accounts National Inventory Report 2012 (manure spread on non-irrigated crops emission factor of 0.01 and fertiliser on non-irrigated crops emission factor of 0.003).

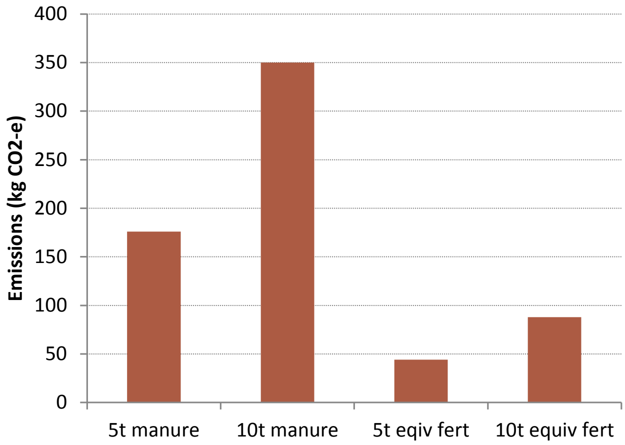


Figure 3. Calculated nitrous oxide emissions

Implications for growers

As expected from the lack of major dry matter responses, there was no significant effect of any on the treatments on soil organic carbon. While 5-10 t/ha of feedlot manure applied every three years is not a large amount of additional dry matter, local growers remain very interested in the long-term impacts on crop performance and soil carbon. Growers need to know if manure applications at these commercial rates have little or no direct impact on soil organic carbon, as it will assist them to make more informed decisions on the most appropriate method of applying the nutrients that their crops need. Lower nitrous oxide emissions are possible with effectively applied inorganic fertiliser in comparison to manures, even though manures are widely considered to increase soil organic carbon.

Yields and dry matters will continue to be monitored and soil carbon will be re-sampled in 2017.

Acknowledgements

The team would like to thank the co-operators for hosting this trial and the Grains Research and Development Corporation and the Department of Agriculture and Fisheries for funding this project.

Trial details

Location:	Warra, Queensland
Crop:	Sorghum (2013), Chickpea (2014)
Soil type:	Black vertosol
Fertiliser:	as per treatment list

Harvesting sorghum off the trial

Increasing soil organic matter: establishing productive pasture on long-term cropping country - Brigalow

Jayne Gentry, Dr David Lawrence and James Hagan
Department of Agriculture and Fisheries

Research Question: *What is the soil carbon benefit of establishing a productive pasture on long-term cropping country comparing grass only, grass with a legume versus grass plus 100 kg nitrogen/ha/yr?*

Key findings

1. The grass-only plots produced significantly more dry matter when planted into moisture
2. There was a large increase in dry matter with the addition of 100 kg nitrogen/ha each year
3. There were no statistically significant changes in soil organic carbon, which was expected in the short term (two years)

Background

The establishment of a productive sown grass pasture phase is the most promising practice available to mixed farmers looking to improve their soil organic carbon levels on degraded cropping land. However, these pastures must be well grown with good nutrient supplies to make a major contribution. Consequently, nitrogen is required in most old cropping soils that have low levels of available nitrogen due to their declining soil carbon levels. This nitrogen can be supplied to the system by the inclusion of a legume in the pasture mix or by the addition of nitrogen fertiliser. The team were interested in comparing the effectiveness of three different approaches on increasing pasture production and ultimately soil carbon.

Soil organic carbon benefits will be greatest where pastures are established quickly and produce large quantities of dry matter. However, pasture establishment is very often poorly done and as a result the increased time out of production waiting for a good pasture to graze is costly. It is considered that the best method to establish a productive pasture as quickly as possible is to 'plant it like a crop'; that is plant into soil moisture into a paddock where weeds have been effectively controlled. At Brigalow, these pastures were planted by spreading seed on the surface (surface sown) to represent 'current practice' as well as being direct drilled into moisture (deep sown) to demonstrate the potential to establish a pasture more rapidly using modern agronomy.

Treatments

The treatments were:

- Grass only surface sown (Bambatsi panic)
- Grass only deep sown (Bambatsi panic)
- Grass-legume surface sown (Bambatsi panic and Burgundy bean)
- Grass-legume deep sown (Bambatsi panic and Burgundy bean)
- Grass only deep sown (Bambatsi panic) plus 100 kg N/ha/yr

These pastures were planted in February 2013 with research equipment into plots approximately 15 m x 6 m. Unfortunately the trial was flooded a few weeks later, however it was replanted in November 2013. Urea fertiliser was surface applied at 100 kg N /ha in 2014 and 2015.

Results

Total dry matter production over the life of the trial was significantly higher (P=0.05) in the pure grass pasture compared to the mixed grass/legume pastures. The two grass/legume treatments are likely to become more competitive as the pastures become older and the available nitrogen levels decline. While there was no significant impact of deep sowing the grass/legume pastures into moisture like a crop, the grass-only plots produced significantly more dry matter when deep sown (P=0.05). However, the major difference was the large increase in dry matter that was achieved with the addition of 100 N kg/ha each year, and this response may

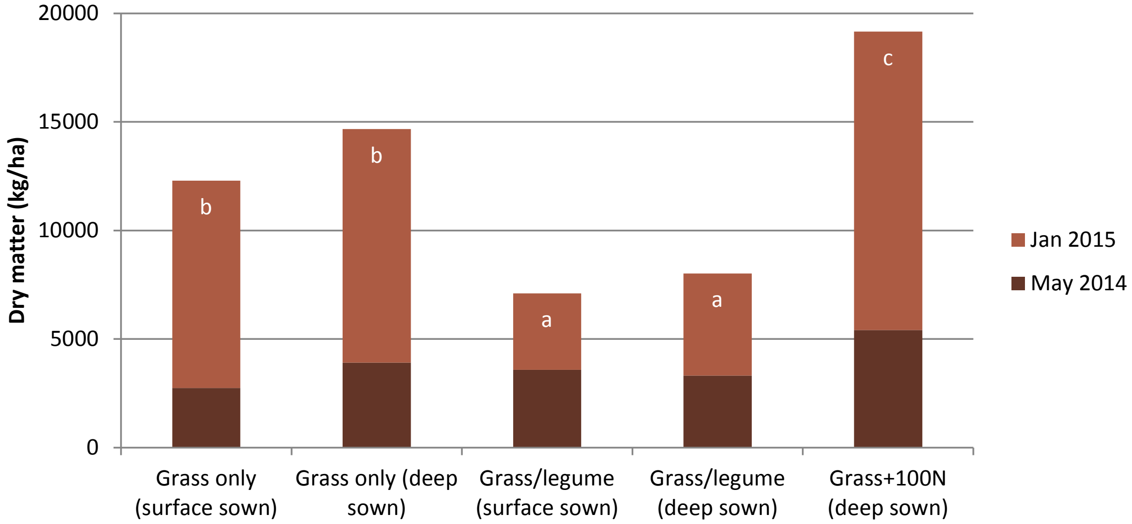


Figure 1. Dry matter production. Bars with the same letter are not significantly different at the 5% level.

Table 1. Soil organic carbon stock (t/ha)(in 0-30 cm; BD (0-10) =1.28; BD (10-30) = 1.59)

Date sampled	Grass only (surface sown)	Grass only (deep sown)	Grass/legume (surface sown)	Grass/legume (deep sown)	Grass+100N (deep sown)
December 2012 (standard error)	mean 28.8 t/ha (Std error 0.769)				
March 2015 (standard error)	Not sampled	30.95 (0.976)	Not sampled	Not sampled	30.94 (0.98)

become larger as the nitrogen mineralised prior to planting is immobilised by the grasses.

The total organic carbon levels on this soil (0.82%, Std error 0.0162 for 0-10cm; 0.58%, Std error 0.0225 for 10-30 cm) are low but typical for a paddock in the area that has been cropped for 100 years. Under remnant vegetation they would again be expected to be 3.0-3.5 % in the 0-10 cm layers of the soil. This suggests that high dry matter production systems, like a fertilised grass pasture, have potential to sequester significant amounts of carbon over a 10-20 year period.

The key 'grass-only (deep sown)' and the 'grass-only (deep sown) + 100N' treatments were re-sampled in May 2015, although no differences were expected due to the short period of growth in the trial. A slight increase in carbon stocks was calculated in both the grass and grass plus nitrogen treatments, but the results are not yet statistically significant.

Despite the lack of a significant increase in soil carbon levels there may still be economic benefit from increased dry matter production.

Pasture production benefits require the conversion of pasture to livestock live weight gains, using conservative estimates of 12:1 conversion efficiency, with 40% of additional dry matter production being consumed and a live weight price of $3/kg. Table 2 attempts to place a value on the treatments in this trial. The trial treatments are compared to grass surface treatment assuming it most closely reflects standard practice.

Table 2. Economics of treatments for increasing soil carbon

Treatment	Total Cost * ($/ha)	Total DM (kg)	Total Benefit kg/ha	Total Benefit $/ha
Grass Surface	5	12500	0	0
Grass (Deep Sown)	8	14800	2300	227
Grass/Legume (Surface)	5	7000	-5500	-550
Grass/Legume (Deep Sown)	8	8000	-4500	-453
Grass + 100N (Deep Sown)	160	18000	5500	395

*Note: costs calculated using owner machinery

At the current point in time the grass/legume treatments have produced less dry matter than the grass only treatments. This is expected as the legumes have not had sufficient time to begin to provide a nitrogen benefit, however it is expected in the long run that these grass/legume mixes will provide higher production with a self-replacing source of nitrogen.

The practice of deep planting pasture similar to conventional cropping programs to achieve faster establishment shows merit with a 2300 kg benefit, and when this practice was paired with 100 kg of nitrogen annually the net benefit was 5500 kg, providing almost $400/ha in additional benefit over surface sown grass.

The full set of treatments will be maintained and re-sampled for soil carbon analysis in 2017, which is expected to be sufficient time for the treatments to start to impact on total organic carbon levels in the soil.

Implications for growers

It is believed that there is potential for well grown pasture phases to slow the decline, and/or rebuild total organic carbon in the soil. However, there is strong evidence that pastures must be productive with good nutrient supplies to make a major contribution. Consequently, a source of nitrogen (legumes, fertilisers, manures) will be needed in most old cropping soils that have low levels of available nitrogen due to their declining soil carbon levels.

Acknowledgements

The team would like to thank the co-operator for hosting this trial and the Grains Research and Development Corporation and the Department of Agriculture and Fisheries for funding this project.

Trial details

Location:	Brigalow, Queensland
Crop:	Bambatsi panic, bambatsi panic + burgundy bean
Soil type:	Black vertosol
Fertiliser:	as per treatment list

Inspecting Burgundy bean nodulation

Increasing soil organic matter: applying nitrogen to maximse production – Chinchilla

Jayne Gentry, Dr David Lawrence and James Hagan
Department of Agriculture and Fisheries

Research Question: *What is the soil carbon benefit of applying annual nitrogen applications on established grass pasture?*

Key findings

1. Total dry matter production (2012–2015) more than doubled when comparing grass only to grass + 50 N kg/ha and over tripled when compared to grass + 100 N kg/ha
2. There were statistically significant increases in soil carbon when comparing the grass only to the grass + 100 N kg/h, even within the short time frame

Background

A productive sown grass pasture phase has the greatest potential to improve soil organic carbon levels on degraded cropping land. However, these pastures must be well grown with good nutrient supplies to make a major contribution. Nitrogen is required in most old cropping soils that have low levels of available nitrogen due to their declining soil carbon levels. This nitrogen can be supplied to the system by the inclusion of a legume in the pasture mix or by the addition of nitrogen fertiliser. The team were interested in comparing varying rates of nitrogen to determine which was more effective in increasing biomass production and ultimately soil carbon.

Treatments

The following treatments were applied to a two year old Rhodes grass pasture:

- Grass only
- Grass + 50 N kg/ha/year
- Grass + 100 N kg/ha/year

The fertiliser treatments were initially applied in November 2012 to this young pasture and have been repeated annually.

Results

The floods of 2012 damaged the grazier's fence and stock grazed the paddock prior to the first cut, which was subsequently estimated visually. However, a second cut in May 2013 prior to frosts, still showed a carry-over yield response to the applied nitrogen of up to 20 kg dry matter/kg N. Subsequent years have been less productive but significant total dry matter responses have still been measured between all treatments over the life of the trial. The addition of 50 N kg/ha more than doubled the dry matter production and the 100 N kg/ha treatment more than tripled dry matter production in comparison to the grass only treatment.

Total organic carbon levels on this soil were extremely low (0.23%, Std error 0.0118 for 0-10 cm; 0.12%, Std error 0.0118 for 10-30 cm) and illustrate the impact of cropping these lighter textured soil in the region. However, these lighter soils may also respond more rapidly to the additional dry matter produced by a productive pasture; and so this site was expected to show significant increase in soil carbon levels within this short time frame.

Table 1. Soil Organic Carbon stock (t/ha) in 0-30 cm (BD (0-10) = 1.31; BD (10-30) = 1.53)

Date sampled	Grass only	Grass +50N	Grass +100N
December 2012 (standard error)	mean 6.78 t/ha (Std error 0.399)		
March 2015 (standard error)	8.22 (1.272)	Not sampled	8.08 (0.537)

The unfertilised and 100 N kg/ha/year treatments were re-sampled in May 2015 and show statistically significant increases in soil organic carbon. This site, on a lighter loam soil, showed an increase in carbon stocks (P=0.062) under pastures within approximately two years. This soil had very low soil carbon stocks to 30 cm, but increased from 6.8 t/ha to 8.2 t/ha. The Total Organic Carbon level in the top 10 cm increased from 0.23% to 0.30% with the growth of the pastures over the life of the project (P=0.02). Despite nitrogen fertiliser treatments

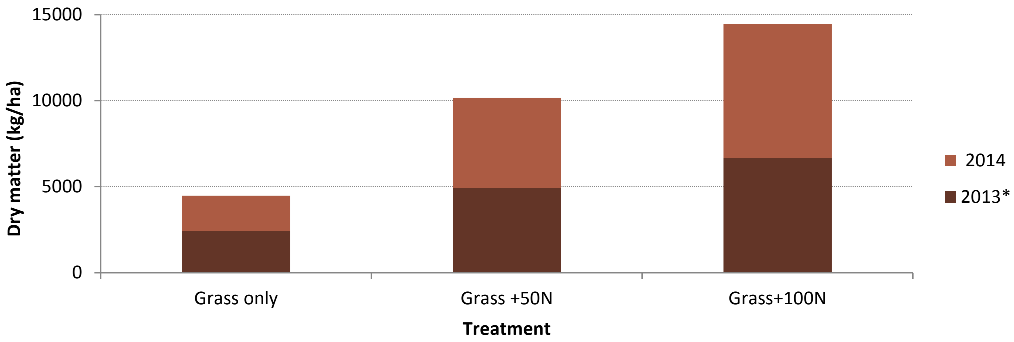


Figure 1. Dry matter production (*visual estimates in Jan 2013)

at this site providing large increases in dry matter production, these differences were not yet reflected in soil organic carbon results.

Whilst the economic benefit from this increased dry matter production on crop yields due to soil carbon increases is currently unknown, increased pasture production can be economically valuable in itself.

Table 2. Economic benefit of improved dry matter production

Treatment (N)	Total DM production (kg/ha)	Total N Cost ($/ha)	Total Dry Matter Benefit (kg/ha)	Total Benefit ($/ha)
0	4800	0	0	0
50	10100	79	5300	530
100	14500	155	9700	970

The addition of 50 kg N/ha annually provided 5.3 tonne of additional dry matter, and whilst the nutritional value of the dry matter, and the conversion efficiency of whichever livestock grazed it, we can estimate these values. Using conservative values of 12:1 Food Conversion Efficiency, a liveweight beef price of $3/kg, and assuming 40% of additional dry matter is consumed provides 212 kg of live weight gain and a benefit of over $636 over the two years. Using these same assumptions the addition of 100 kg N/ha could have provided a benefit of over $1164 over the same two years.

This trial will receive further annual applications of nitrogen fertiliser and soil carbon will be retested in 2017.

Implications for growers

It is considered that productive, well grown pasture phases have the greatest potential to slow the decline, and/or rebuild total organic carbon in the soil. However, research suggests in order to increase soil organic carbon, pastures require adequate nutrient supplies to maximise productivity. Hence, most old cropping soils will require a source of nitrogen (which can be provided by legumes, manures, or in this case fertilisers), due to their low soil carbon levels.

Acknowledgements

The team would like to thank the co-operator for hosting this trial and the Grains Research and Development Corporation and the Department of Agriculture and Fisheries for funding this project.

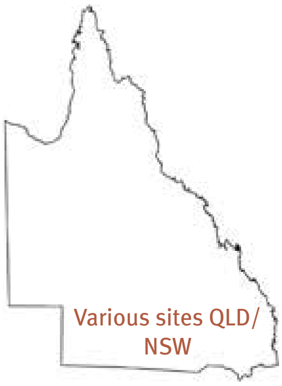
Trial details

Location:	Chinchilla, Queensland
Crop:	Rhodes grass pasture
Soil type:	Light loam
Fertiliser:	as per treatment list

Nitrogen applied to established pasture plots

The impact of grain production and farming practices on soil organic matter levels

Dr David Lawrence and Jayne Gentry
Department of Agriculture and Fisheries



Research Questions: *How does long-term grain cropping effect soil organic matter levels in Queensland? | What farming practices can rebuild soil organic matter levels in grain cropping soils?*

Key findings

1. Grain cropping can reduce soil organic matter and soil carbon levels by up to 70%
2. In-crop agronomy has much less effect than major land use changes, such as clearing land for cropping, on soil organic matter and soil carbon levels
3. Well grown pasture phases, especially those with legumes included, appear to have the greatest potential to rebuild soil organic matter and soil carbon levels in old cropping soils

Background

Soil organic matter (SOM) is critical for healthy soils and sustainable agricultural production; it contains organic carbon that underpins many physical, chemical and biological soil processes in the soil, and a range of elements needed by both plants and soil biota (Hoyle, Baldock and Murphy 2011). We all know that SOM is good for the soil and that crops growing in healthy soils with high SOM levels are easier to manage and perform better. However, the recent dialogue about 'climate change', Australia's emerging 'carbon economy' and opportunities to trade sequestered soil carbon have renewed interest in better understanding SOM, the soil organic carbon (SOC) levels we use to measure it, and how best to manage them on commercial grain farms.

Levels of SOC are the result of the balance between inputs (e.g. plant residues and other organic inputs) and losses (e.g. erosion, decomposition, harvested material) in each soil and farming system (Hoyle, Baldock and Murphy 2011). Maximising total dry matter production will encourage higher SOC levels. Clearing native vegetation for grain cropping will typically reduce SOC and SOM levels (Dalal and Mayer 1986). Research was initiated to assess the extent of the decline in SOC under grain cropping and identify cropping practices that have the potential to increase or maintain SOC and SOM levels at the highest levels possible in a productive cropping system.

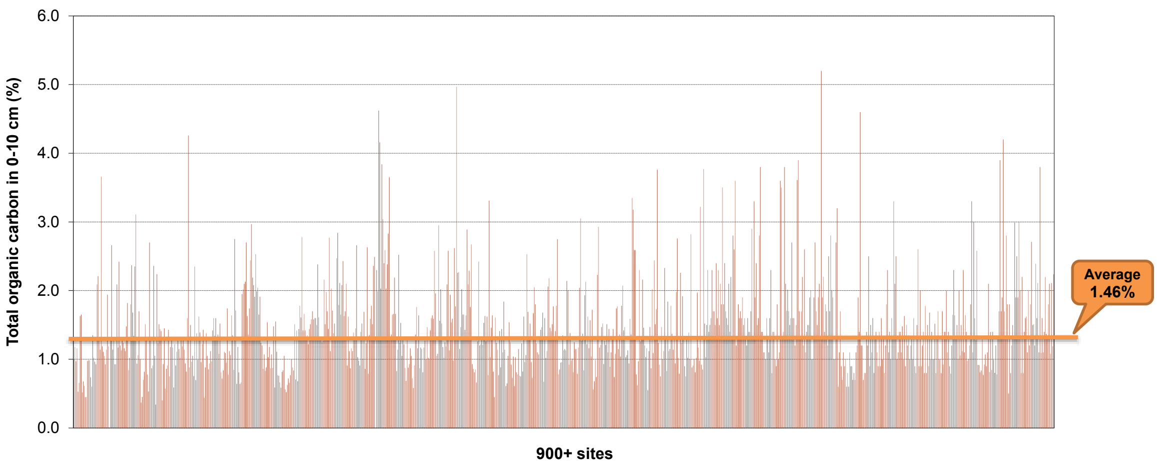


Figure 1: Total soil organic carbon (0-10 cm) levels across all sites in the northern grains region

Treatments

Changes in SOC and SOM levels occur slowly, so long-term experiments that last at least 5-10 years are needed to measure significant changes in the Total Organic Carbon levels in the soil. A series of ~500 paired-site comparisons were used to estimate the impacts of long-term cropping and major farming practices on SOC across Queensland. Each comparison chose two paddocks with the same soil on each property, but with different land-use histories and a range of farming practices that had been implemented for at least 5-10 years. Any differences in SOC levels between the two paddocks with the same soil on each farm were attributed to the different practices that had been used.

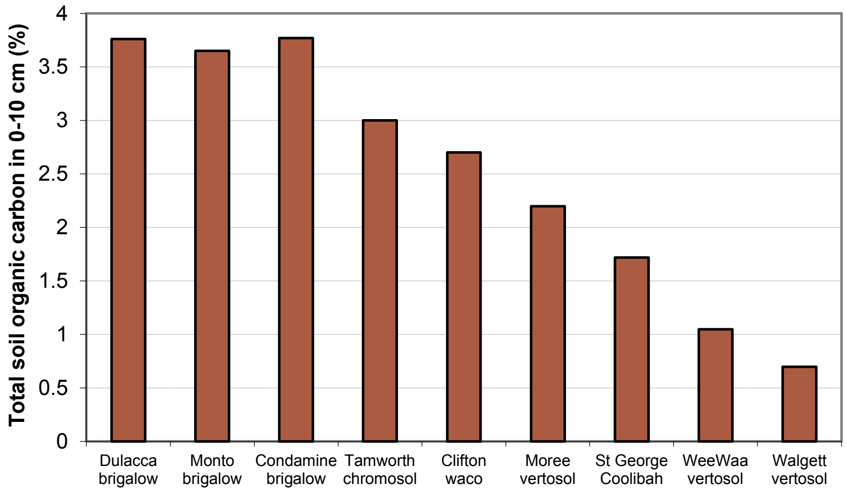


Figure 2. Impact of location/land type on Total Organic Carbon under remnant vegetation

Results

Total SOC (0-10 cm) levels varied enormously across sites. The average was 1.46% however it varied from under 0.5% to over 5% (Figure 1).

On average, 56% of the total organic carbon stocks to 30 cm occurred in the 0-10 cm layer but this varied from 21-74% on individual paddocks. The results from remnant vegetation (Figure 2) reinforced the impact of climate, soil type and vegetation on the biological potential of soils to sequester carbon. For example, Brigalow soils at Roma have lower SOC levels than similar soil in more the favourable climate of Jandowae. However, the drivers of SOC declines and increases only became clear when specific land use and farming practices were compared.

Declines in soil organic carbon

The most consistent land use impact on SOC was the decline when country was cleared for long-term cultivation (Figure 3). Soil carbon levels under remnant vegetation also varied with soil type and location, but there was a clear and dramatic impact of clearing and cultivating for 20+ years. The reductions in Total Organic Carbon were most dramatic on the highly fertile Brigalow soils in southern Queensland, where declines of 60-70% (equivalent to ~2.5% Total Organic Carbon) were common. This represents a decline in the natural nutrient capital to a depth of 30 cm in these soils of up to $5000-8000/ha (Lawrence *et al*. 2013).

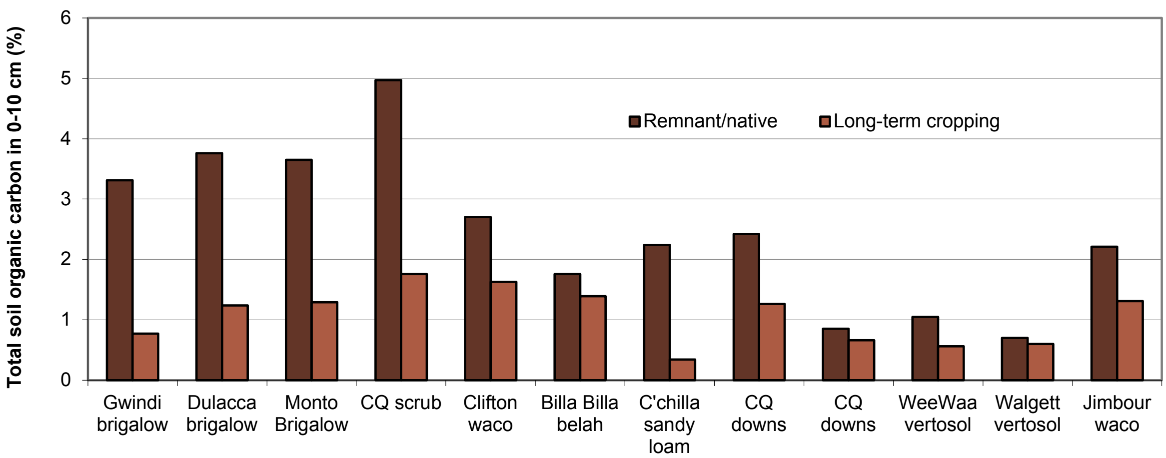


Figure 3. The impact of long-term cropping (20+ years) on Total Organic Carbon

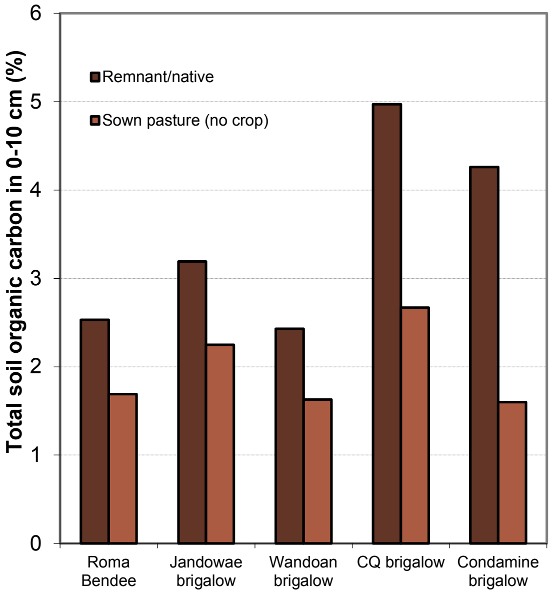


Figure 4. Reductions in Total Organic Carbon (0-10 cm) when land is cleared for sown pastures

The development of land for pastures also resulted in a decline in the underlying SOC concentrations. These declines were not as dramatic as development for cropping, but confirmed that the native vegetation that typically included some trees and shrubs produced higher dry matter levels than cleared pastures (Figure 4). The data also supported the use of sown pastures for extra production, which was reflected in higher SOC levels than comparable native pastures in nearly all cases (Figure 5).

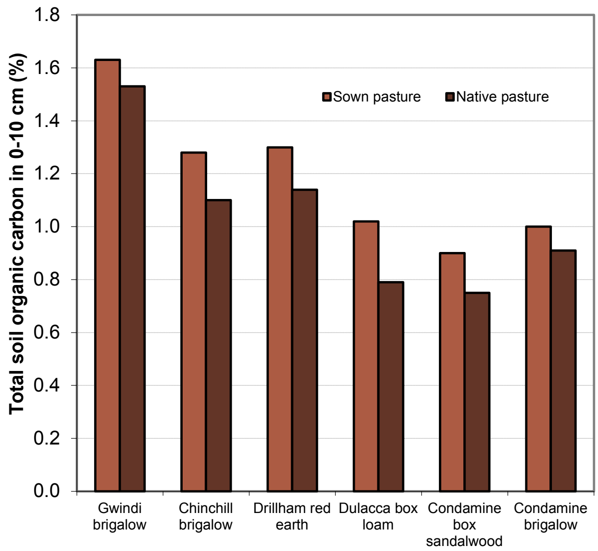


Figure 5. Total Organic Carbon levels (0-10 cm) under comparable sown and native pastures

Rebuilding soil organic carbon levels with pastures

The paired-site comparisons were also used to explore the potential of key practices to rebuild SOC in cropping systems. The most commonly investigated option was the return of long-term cropping paddocks to pastures. This is a practical option for many people because the majority of grain producers in the northern region run 'mixed' enterprises with significant areas of land used for grazing, most commonly for beef cattle production.

SOC levels were higher in the vast majority of paddocks that had been returned to pastures for at least five years, in the more marginal Western downs districts (Figure 6) and the higher rainfall Darling Downs. There were several isolated cases where the pasture paddock had a lower SOC but in each case, the farmers subsequently confirmed that those paddocks were returned to pasture because they were not performing in the first instance (due to some confounding influence).

A more detailed investigation of the changes in SOC suggested that the difference between the cropping paddocks and those resown to pastures could be at least 1 t/ha/yr in highly productive pastures (Table 1). However, there were also some pastures that had provided little if any increase in SOC after many years. This data needs further investigation as the paired site comparisons may include a range of confounding factors. However, discussion within the farmer groups and the project team strongly suggests that the determining factor was the presence of legumes in the better performing pastures and their absence in the poorer performing paddocks.

The three-way comparisons between remnant vegetation, long-term cropping and long-term cropping land returned to pastures also revealed a variable ability of pastures to build or maintain SOC (Figure 7). Re-investigation of the soil test data for these sites suggested that the recovery in soil carbon was related to the underlying soil phosphorus levels and the subsequent level of legume growth in the pasture phase:

- The best performing pasture for rebuilding SOC (Roma) had high phosphorus levels and strong legume (medic) growth which may supply up to 30 kg N/ha/yr. This extra nitrogen is capable of producing an additional 900-1200 kg dry matter each year, which may support more stock and contribute strongly to the SOC.

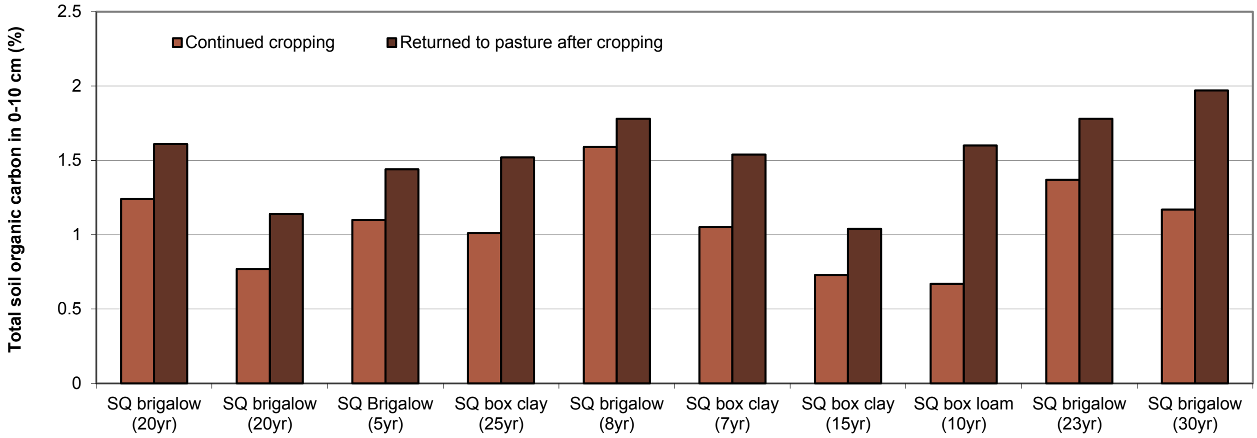


Figure 6. Total Organic Carbon comparisons for crop lands resown to pasture (Western Downs)

Table 1. Examples of the change in carbon stocks when crop land was returned to pastures

Location	Soil/vegetation	Crop (years)	Pasture (years)	Carbon stocks (t/ha)	Δ Carbon (t/ha/yr)
Samples to 30 cm (0-10 cm + 10-30 cm) using conservative Bulk Densities of 0-10: 1.25 & 10-30: 1.3					
Warra	Brigalow Clay	75 65	0 10 (sown grass/legume)	26 52	+ 2.6 t/ha/yr
McCallister	Waco clay	60 50	0 10 native grass	44 54	+1 t/ha/yr
Jandowae	Brigalow clay	40+ (baled) 40+	0 40 (sown grass)	49 63	+0.4 t/ha/yr
Nindigully	Red box loam	40 30	0 10 (sown grass)	28 31	+0.3 t/ha/yr
Nindigully	Coolibah clay	25-30 25-30	0 10 (sown grass)	17 21	+0.4 t/ha/yr
Samples to 10 cm only using conservative Bulk Densities of 0-10: 1.25					
Warra	Brigalow clay	45 35	0 10 (sown grass/medic)	12 17	+0.5 t/ha/yr
Glenmorgan	Box wilga loam	25 15	0 10 (sown grass/medic)	8 20	+1.2 t/ha/yr
Condamine	Brigalow belah clay	40 30	0 10 (sown grass/medic)	15 25	+1 t/ha/yr
Talwood	Red clay	40 40	0 7 (sown grass/medic)	13 19	+0.9 t/ha/yr
Talwood	Brigalow clay	15 15	0 3 (sown grass)	14 18	+1.3 t/ha/yr
Talwood	Grey Clay	25 15	0 10 (sown grass)	9 13	+0.4 t/ha/yr
Goondiwindi	Brigalow belah clay	30 30	0 20 (sown grass)	16 20	+0.2 t/ha/yr
Condamine	Belah wilga clay	35	0 15 (native grass)	12 12	+0 t/ha/yr

- In contrast, the pasture with no carbon impact (Condamine) was extremely deficient in phosphorus (bicarbonate phosphorus 0-10 cm of 3 mg/kg) and had no legume growth. This would leave the pasture with little dry matter production due to extreme nitrogen deficiency after a cropping phase. This pasture may never recover without remedial action, and the farmer may have low dry matter levels, poor beef production and little increase in SOC for the foreseeable future.

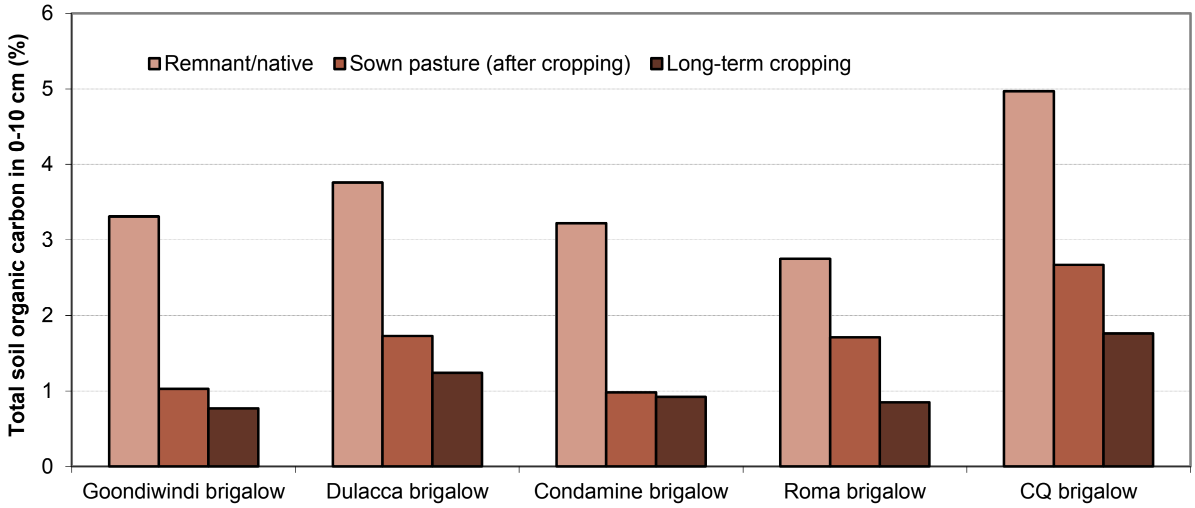


Figure 7. Three-way comparisons of the Total Organic Carbon impacts of cropping and resowing pastures

This insight on the importance of soil phosphorus had a major impact on the participants in the project. Indeed, it was the catalyst for many of the mixed farmers developing strategies to maintain soil phosphorus levels on their cropping country. This will enable them to move between enterprises and maintain the ability to use pastures to rebuild SOC and soil health levels into the future.

Rebuilding soil organic carbon levels with cropping practices

While mixed farmers may be able to use pasture phases to manage their SOC levels, most farmers were also interested in their options for permanent cropping paddocks. Consequently, they assessed a range of agronomic practices in the paired-site comparisons for the possible impacts on carbon. In each case, the impacts of these different agronomic practices were minor at best and will require more rigorous research to clarify any statistically significant impacts:

- Selecting crops with different levels of dry matter (e.g. cotton vs grain). Ultimately, the differences were minor, reinforcing the overarching impact of a prolonged fallow in the northern farming systems. This result was re-assuring for some cotton growers who were concerned that cotton farming systems that use long fallows were further degrading their soils;
- Planting forage crops with potential for higher dry matter production was also considered to be a good option to maintain soil carbon at higher levels than grain crops. Again, the differences were minor at best (Figure 8). It was suggested that many forage crops under-performed as they were not managed or fertilised as well as grain crops, and that stock often redistributed much of their residue via manure around watering points and shade lines. Again, the fallow period in the northern system appeared to be a dominant effect.
- Manures were of particular interest to solely grain producers. It is logical that any added dry matter via organic fertilisers must at some level increase soil carbon levels. However, the results in the project comparisons showed no real benefit from the commercially used rates of manure, presumably due to the low rates commonly used and the rapid breakdown of labile carbon in the manures. No comparisons of repeated use of heavy manure rates were available on crop land as farmers with feedlots spread manure on all their cropping paddocks. If anything, the results were lower where manures and other biological products were periodically used, perhaps due to people reducing the overall amount of nutrients added when using manures and organic product; or microbial ‘priming’ from the addition of labile carbon. The key insight was to ensure that the nutritional needs of crops are properly addressed and that compost teas and other products

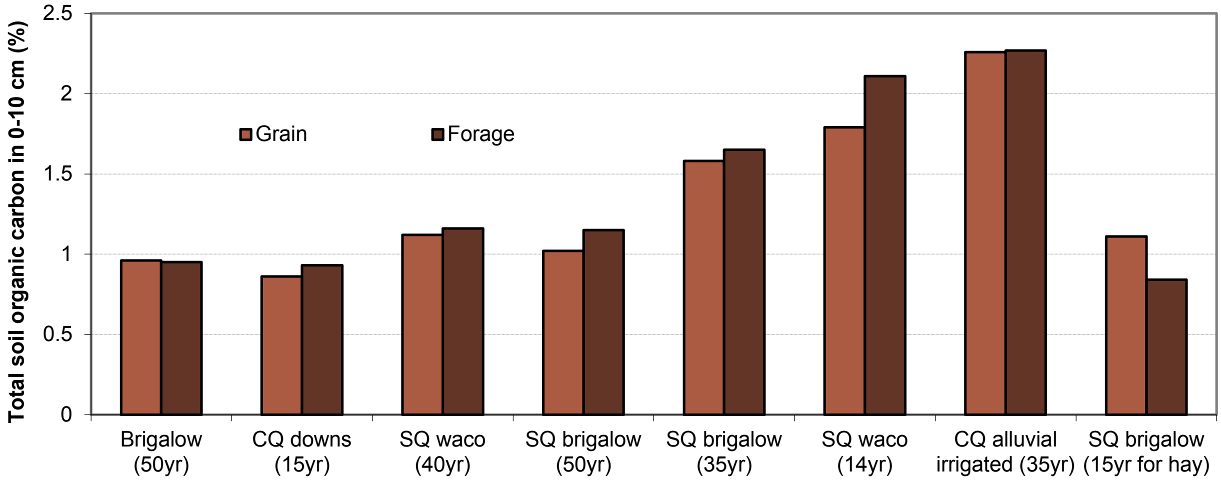


Figure 8. Total Organic Carbon levels under long-term grain and forage cropping

alone are not going to overcome nutrient deficiencies.

- Using modern farming systems practices with reduced tillage and high nutrient replacement rates. This modern system was compared because the project was unable to locate separate comparisons of these tillage practices and of high nutrient applications on paired paddocks; farmers tend to change these practices across their whole farm. While the data suggest there may be a small impact of modern practices on maintaining soil carbon levels, this comparison requires further investigation with more rigorous experimental methods.

Implications for growers

Long-term grain production clearly reduces SOC (and hence organic matter) levels. On well-structured soil this decline and the subsequent loss of soil nutrients such as nitrogen may be managed by increased rates of fertiliser. However, management will need to be spot-on as the soil will become less resilient with lower nutrient reserves and hence be less able to respond to seasonal changes. These soils will also be more prone to disease, so again, good agronomy and timely management will be critical. For grain-only producers, strategies to maintain soil organic carbon will need to focus on using the best possible agronomy to grow the best crops, with as much dry matter as possible, as often as possible; balanced with the need for each crop to be profitable. The project comparisons also confirm that mixed farmers have much greater potential to rebuild and manage their SOC and SOM levels than grain-only farmers; they have the potential to use well grown and productive pasture phases.

Acknowledgements

Thanks to the many farmers, agronomists and farmer groups that helped coordinate the program across Queensland.

The project was funded by the Grains Research and Development Corporation, the Department of Agriculture and Fisheries and the 'Action on the Ground' program of the Australian Government through the Department of Agriculture.

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Farming systems research

Advances in agronomy and the performance of individual crops have helped growers to maintain their profitability. However, there is evidence that current farming systems are under-performing.

Research suggests that only 30% of the crop sequences currently used across the northern grains region achieve 75% of their water limited yield potential. Northern farming systems are also being challenged with increasing herbicide resistance, declining soil fertility and increasing soil-borne pathogens. Changes will be needed in our farming systems to meet these new challenges and to maintain system productivity. The Northern Farming Systems initiative was consequently established around the question;

> ***Can systems performance be improved by modifying farming systems in the northern grains region?***

This research question is being addressed at two levels; to look at the systems performance across the whole grains region, and to provide rigorous data on the performance of local farming systems at key locations across Queensland and New South Wales.

Regional agronomists began research with local growers and agronomists in 2015 to identify the key limitations, consequences and economic drivers of farming systems in the northern region; to assess the performance of promising farming systems and crop sequences that deal with the emerging challenges; and to develop the systems with the most potential for use across the northern region. Experiments were established at seven locations, with a large factorial experiment managed by CSIRO at Pampas near Toowoomba, with locally relevant systems being studied across six regional locations by the Department of Agriculture and Fisheries in Queensland and the Department of Primary Industries in New South Wales (Table 1).

Several of these systems are represented at every site to allow major insights across the northern region, with site specific systems also included to provide insights for local conditions. Details of the specific system being studied at each site and the way they are implemented locally are included in the following reports for each of the experiments in regional Queensland.

While it is early days, the initial results from each of the regional sites in Queensland are reported here in this first 'Trial Book':

- **Emerald** – at the Emerald Agricultural College on a grey vertosol. This site has a unique 'Integrated weed management' system which was critical to include for local relevance;
- **Mungindi** – ~20 km north of Mungindi on a 25 year old grey vertosol. The site has six systems that have been planned and developed in collaboration with the Mungindi Cropping Group and their supporting agronomists; and
- **Billa Billa** – 50 km north of Goondiwindi on a 15 year old and so relatively fertile brown 'belah' clay soil. This large site has nine systems and incorporates two pasture phases (+/- 100 kg N/ha/year).

Table 1. Summary of the regional farming systems being studied at each location

	Regional sites					
System	Emerald	Billa Billa	Mungindi	Spring Ridge	Narrabri	Trangie x2 (Red & Grey)
Baseline – represents a typical zero tillage farming system	*	*	*	*	*	*
Higher nutrient supply – as for the 'Baseline' system but with fertilisers for 100% Phosphorus replacement and nitrogen targeted at 90% of the yield potential each season	*	*	*	*	*	*
Higher legume – 50% of the crops are sown to legumes	*	*	*	*	*	*
Higher crop diversity – a wider range of crops are introduced to manage nematodes, diseases and herbicide resistance		*	*	*	*	*
Higher crop intensity – a lower soil moisture threshold is used to increase the number of crops per decade	*	*		*	*	*
Lower crop intensity – crops are only planted when there is a near full profile of soil moisture to ensure individual crops are higher yielding and more profitable		*	*	*	*	*
Grass pasture rotations – pasture rotations are used to manage soil fertility. One treatment has no additional nitrogen fertiliser, while the other has 100 kg N/ha/year to boost grass production		*				
Higher fertility (higher nutrient supply plus organic matter) – as in the high nutrient system but with compost/manure added	*	*				
Integrated weed management (incl. tillage) – this system is included at Emerald where crops, sowing rates, row spacings and 'strategic tillage' are included to manage weeds and herbicide resistance	*					

Wheat at the Emerald farming systems trial

Northern Farming Systems site - Emerald

Darren Aisthorpe
Department of Agriculture and Fisheries

***Research Question:** What are the long-term impacts on systems performance (e.g. productivity, profitability and soil health) when six strategically different "farming systems" are applied over 5-10 years at Emerald?*

Key findings

1. Chickpeas were more efficient than wheat in converting biomass to yield in a tough year
2. Good nutrition assists with crop yield despite low populations and high starting nitrogen
3. Wheat compensated surprisingly well despite poor establishment in CQ conditions

Background

The Emerald Northern Farming Systems (NFS) trial is the most northerly of the seven farming systems experiments across the grains region. The experiment is located on a cracking, self-mulching grey vertosol at the Emerald Agricultural College. The soil is over 1.5 m deep with a Plant Available Water Capacity (PAWC) of 170–200 mm. The recent cropping history at the site is:

- Summer 12/13 – sorghum
- Summer 13/14 – irrigated cotton
- Summer 14/15 – the field was acquired for the trial
- First planting – May 2015

The field was a bare fallow and had been worked several times prior to being selected for the NFS trial. A cover crop of forage was planted in early January 2015 and grown with supplementary irrigation to accelerate the process back to a zero till system by creating cover and improving the soil structure prior to the first crops being planted. The forage crop was slashed in the third week of February and the regrowth was sprayed out in the first week of March. Pre-plant irrigation enabled crops to be planted for each treatment in the first season. Further site preparation details include:

- A deep phosphorus application of 200 kg/ha of Granulock Z® across the whole site on 50 cm spacing and 15-20 cm depth to remove phosphorus as a constraint
- Pre-plant nitrogen applied based on previous field cores
- 20 t/ha of manure was applied to high fertility treatments
- Residual herbicides applied to pulse crop treatments

Consultative meetings were held with selected consultants and growers in Emerald and Biloela during 2015 to:

- Determine the relevant systems to Central Queensland (CQ). The systems described below are variation of the practices in the initial 'baseline' system
- Set 'rules' or trigger points, such as crop selection, planting moistures and windows to ensure the six systems are relevant to farming practices across Central Queensland.

Treatments

1. **Baseline** - A moderately conservative zero tillage system in-line with common practices. The system is based on ~1 crop/year with nutrition applied to match 50th percentile yield expectation for the measured planting water. Crops include wheat, chickpea, sorghum
2. **Higher legume** – The frequency of pulses is increased in this system (i.e. 1 pulse every 2 years) to assess the impact of more legumes on profitability, soil fertility, disease and weeds. Crops include wheat, chickpea (but not chickpea on chickpea), sorghum, mungbean and new legume crops
3. **Higher crop intensity** – This system increases the crop intensity to ~1.5 crops/year to see whether a higher cropping intensity is more profitable in the long-term. Is a higher risk strategy that plants into lower plant available water (PAW) more sustainable from both an agronomic and economic point of view? Crops include wheat, chickpea, sorghum, mungbean and forage crops/legumes

4. **Higher nutrient supply** – Fertilisers are applied to ensure adequate nutrition for 90% of the potential yield based on soil moisture at planting. So, what are the economic and soil implications of targeting higher yields with increased nitrogen and phosphorus within Central Queensland's variable climate? The crops and other practices are the same as the Baseline system
5. **Higher soil fertility** - This system is a repeat of the higher nutrient supply system but with the addition of 20 t/ha of manure in the first year. The system is designed to see if higher initial soil fertility can be maintained with greater nutrient inputs
6. **Integrated weed management** – This minimum tillage system is focused on 1 crop/year but employs a wide range of practices to reduce the reliance on traditional knock-down herbicides in Central Queensland farming systems. Practices include tillage with full disturbance planting, herbicides (contact & residual), and other cultural practices (high plant population, narrow rows, crop choice, other emerging technologies). Crops include wheat, chickpea, sorghum and mungbeans

Results

2015 was a particularly dry year for the Emerald site. Supplementary overhead irrigation was applied to allow planting and there was only 31 mm rain across the growing season.

Crops planted were:

- Baseline: wheat
- Higher legume: chickpea
- Higher crop intensity: wheat
- Higher nutrient supply: wheat
- Higher soil fertility: wheat
- Integrated weed management: wheat

All treatments were planted on the 13/14 May 2015 under less than ideal conditions following multiple passes to apply nitrogen and phosphorus. This reduced soil moisture and soil seed contact; as a result there was sub-optimal establishment in all treatments except the chickpeas. However, the wheat tillered well during the season and compensated for the poor plant establishments.

Biomass cuts were taken on the 1/9/2015 for the higher legume chickpea crop, and on the 14/9/2015 for the other five wheat treatments at physiological maturity. The chickpeas were harvested on the 22/09/2015 and the wheat on the 8/10/15.

There was a strong correlation between biomass cuts and final yield for all the wheat treatments (Figure 1). However, the harvest index (ratio of grain yield to biomass) was significantly higher for chickpea than the wheat treatments. Wheat grain protein levels were all in excess of 15%, indicating that nitrogen did not limit yields.

There was a yield increase from baseline to integrated weed management treatment that had the advantage of higher plant numbers. The water use efficiency for the baseline and most other systems was between 9-12 kg grain/mm however, the higher plant populations in the

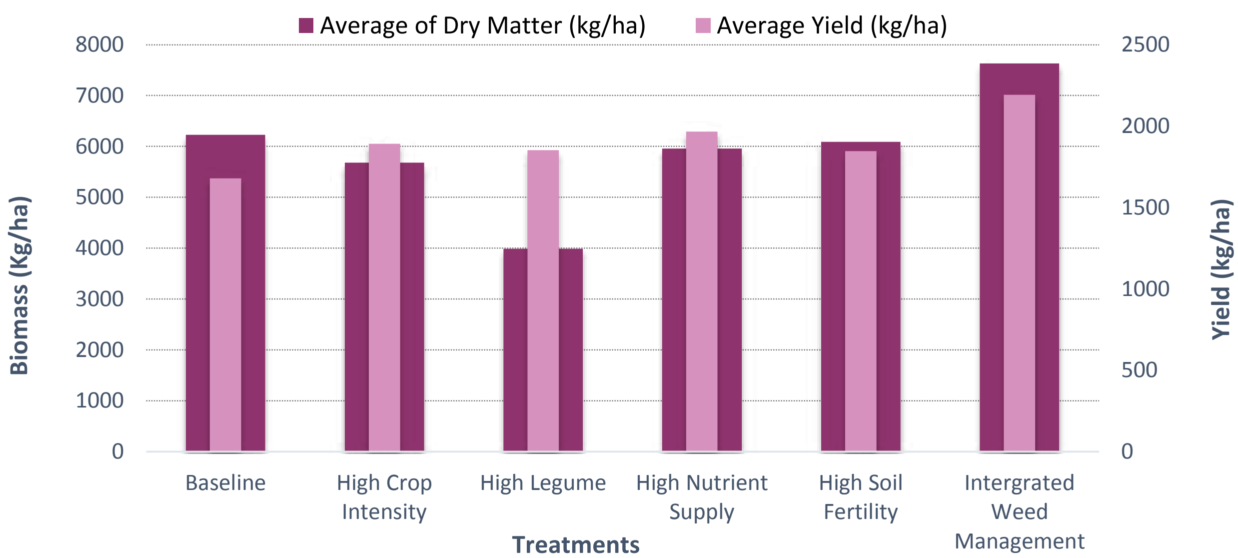


Figure 1. Comparison of average yield to average biomass across all treatments at the Emerald site

Integrated weed management systems achieved a water use efficiency of ~14 kg grain/mm.

The crop struggled in the dry season with significant head tipping observed across all treatments. Screenings were relatively low and test weights were acceptable despite the tough finish.

Table 1. Average grain screenings and test weight across treatments

Treatment	Average of screenings (%)	Average of test weight (kg/Hl)
Baseline	2.9%	83.5
High crop intensity	3.1%	83.6
High legume	n/a	77.8
High nutrient supply	3.1%	83.5
High soil fertility	2.7%	83.9
Integrated weed management	2.9%	83.9
Field average	**2.9%**	**82.7**

Chickpea and wheat planted at the Emerald trial

Implications for growers

The challenges in establishing this first year/first crop setup and the dry conditions limit the conclusions that can be drawn from this initial data set. However, the trial is focused on outcomes and systems comparisons over the next five to 10 years. After late summer rain in 2016, the higher crop intensity treatment was planted to mungbean with good plant establishment. Winter 2016 plantings for all other treatments will begin in early to mid-April for wheat treatments, and early to mid-May for treatments going into chickpea. It is envisaged that differences will therefore start to appear in 2017 as the systems diverge across the experiment.

Acknowledgements

The team would like to thank the growers and advisors who have helped develop this project, and the Grains Research and Development Corporation and the Department of Agriculture and Fisheries for funding the project.

Soil sampling at Emerald farming systems trial

Trial details

Location: Emerald Agricultural College

Soil type: grey vertosol

Treatment	Baseline	High Crop Intensity	High Legume	High Nutrient	High Soil Fertility	Integrated Weed Management
Crop	EGA Gregory⟨D⟩ Wheat	EGA Gregory⟨D⟩ Wheat	Kyabra⟨D⟩ Chickpea	EGA Gregory⟨D⟩ Wheat	EGA Gregory⟨D⟩ Wheat	EGA Gregory⟨D⟩ Wheat
Row Spacing (cm)	50	50	50	50	50	25
In-crop rainfall (mm)	30	30	30	30	30	30
Irrigation (early post emergent) (mm)	50	50	50	50	50	50
Total Nutrition applied (pre and with seed) (kg/ha)						
Urea	134	134	nil	214	134	134
Granulock Z® – deep	200	200	200	200	200	200
Granulock Z® – with seed	16	16	16	32	16	16
Manure (t/ha)	nil	nil	nil	nil	20t/ha	nil

Northern Farming Systems site - Billa Billa

Andrew Erbacher
Department of Agriculture and Fisheries

Research Questions: *Can systems performance be improved by modifying farming systems in the northern grains region? | What are the expected trends in our farming systems? | How will these changes impact on the performance and status of our farming systems?*

Key findings

1. Very low stubble cover meant all treatments were planted to wheat
2. High profile nitrogen levels meant there was no treatment effects measured in a high yielding season

Background

The Billa Billa site is located approximately 50 km north of Goondiwindi on the Leichhardt Highway. The soil is a grey vertosol. The original belah trees were cleared and paddock used as a long-term pasture before being developed for crops 15 years ago.

Billa Billa is in a transitional area between the more favourable eastern Downs and the drier western Downs. The eastern areas have more reliable rainfall, higher inputs and higher yields; and have a greater focus on summer crops that can utilise the more reliable summer rainfall. The western areas have more variable rainfall and lower yields are not uncommon; so growers focus more on winter crops and manage risk by storing more fallow moisture. This site is located in-between these two extremes. The underlying systems are focused on managing risk with a winter dominated cropping program, but investing more in crop nutrition with a significant summer cropping program to assist in disease management.

Each plot within the trial was intensively sampled and analysed in detail for nutrients and root lesion nematodes (by Predicta B) to establish a 'baseline' for monitoring changes over time and to compare the performance of the different systems being implemented. Management of this paddock was consistent with the older adjacent paddocks, resulting in relatively high nutrient inputs for the last 10 years and a subsequently high nitrogen status (Table 1).

Treatments

Consultation meetings in late 2014 and early 2015 developed nine locally relevant systems to investigate at Billa Billa:

1. **Baseline** is typical of local zero tillage farming systems with ~ one crop per year grown using a with moderate planting moisture triggers of ~90 mm plant available water (PAW) for winter and 120 mm PAW for summer. Crops grown in this system are limited to wheat/ barley, chickpea and sorghum, fertilised to achieve average (50%) seasonal yield potential.
2. **Lower crop intensity** reflects a widely used conservative set rotation with a cropping frequency of four crops in five years (0.8/year). The system is wheat/ barley, chickpea, wheat/barley, long fallow, sorghum, long fallow (repeat) with minimum planting PAW and nutrient management similar to baseline.

Table 1. Site averages for initial baseline measures

	Depth	Average Value	Comment
Organic Carbon	0-10 cm	1.2 %	
Nitrogen	0-90 cm	415 kg N/ha	Sufficient to grow 11 t/ha of wheat at 12% protein
Phosphorus (Colwell method)	0-10 cm	21	Probably respond to starter P
	10-30 cm	3	Likely to respond to Deep P fertilizer
Phosphorus (BSES method)	10-30 cm	9	
P. thornei	0-30 cm	17/kg soil	Root lesion nematode present in low and variable populations (0-2878/kg soil)
P. neglectus	0-30 cm	217/kg soil	

3. **Higher crop diversity** allows a greater suite of crops grown to better manage disease, root lesion nematodes and herbicide resistance. Moderate PAW levels for planting each crop (ranging from 90 to 120 mm) have been identified to manage individual crop risk and to target ~one crop per year. These crops will also be fertilised to achieve average seasonal yield potential. The unique rules for this system are focused on managing root lesion nematodes, with 50% crops being resistant to *Pratylenchus thornei* and one in four crops resistant to *Pratylenchus neglectus*. To manage herbicide resistance, two crops of the same herbicide mode-of-action can not follow each other. Crops grown in this system include wheat/barley, chickpea, sorghum, mungbean, maize, faba bean, field pea, canola/mustard and millet.
4. **Higher legume** aims to minimise the use of nitrogen fertiliser by growing every second as a pulse (legume) crop with a preference for those that produce greater biomass and greater carry-over nitrogen benefits. Crops grown in this system are similar to the Baseline (wheat/barley, chickpea, sorghum) with additional pulse options (faba bean, field pea, and mungbean). Moderate PAWs will be applied (90 to 120 mm depending on crop). Crops will be fertilised to achieve average yield potential, with nitrogen only applied to the cereal crops.
5. **Higher intensity** aims to minimise the fallow periods within the system and potentially growing three crops every two years. Crops will be planted on lower PAW (50 mm for winter and 70 mm for summer) and have a greater reliance on in-crop rainfall. Crop choice is the same as the Baseline system, but with mungbeans added as a short double-cropped option.
6. **Higher nutrient supply** will have fertiliser applied to allow the crops to achieve 90% of the maximum seasonal yield potential; with the risk that crops will be over fertilised in some years. This system will be planted to the same crop as the baseline each year, so that the only difference is the amount of nutrients that are applied.
7. **Higher fertility** (higher nutrient supply + organic matter) will be treated the same as Higher nutrient supply, with an upfront addition of organic carbon (compost) to raise the inherent fertility of the site and see if this fertility level can be sustained with the higher nutrient inputs.
8. **Grass ley pasture** will use a perennial Bambatsi grass pasture to increase the soil carbon levels naturally. After three to five years the pasture will removed and returned to the baseline cropping system to quantify the benefits gained by the pasture phase. The pasture will be managed with short duration grazing or simulated grazing with a forage harvester to utilise a pre-determined amount of biomass.
9. **Grass ley pasture + nitrogen fertiliser** repeats the grass ley pasture of 'System 8' but will have 100 kg N/ha (217 kg/ha urea) applied each year over the growing season. This boosts dry matter production that is almost always constrained by nitrogen deficiency in grass-based pastures.

Results

The last commercial crop grown in this paddock was chickpeas in 2014, which left the paddock extremely bare. Consequently, all treatments were planted to EGA Gregory⁽ᴰ⁾ wheat in May 2015. The high nitrogen levels at this site meant that the only treatment difference was that the high nutrient supply plots had a higher rate of starter fertiliser (60 kg/ha vs 17 kg/ha of Granulock Z®). Subsequently there was no difference in yield or protein for any of the systems in this season (Figure 1).

The crop had 140 mm PAW at planting and 140 mm in-crop rainfall. The season produced a 'site average' yield of 4.75 t/ha at 12.9% protein, 3% screenings and a test weight of 76 kg/hL. The water use efficiency (WUE) for this site average was 17 kg grain/mm water.

The adjoining paddock has a much longer cropping history, and therefore has higher requirement for nitrogen fertiliser. This paddock was managed based on soil tests from the older area for the last 10 years, so has had extra nitrogen applied over multiple seasons. Nitrogen in the profile at planting was 415 kg N/ha, which is enough to grow 11 t/ha of wheat at 12%

protein. Post-harvest soils tests indicate that 230 kg N/ha was not used by the 2015 wheat crop.

The pasture plots were also planted to EGA Gregory$^{\mathrm{(D)}}$ wheat as a cover crop to get stubble and soil protection for the establishing pasture. This wheat was sprayed out at booting (August) with a dry matter production of 5 t/ha. These plots were then planted to Bambatsi on 2 November with a PAW of 140 mm.

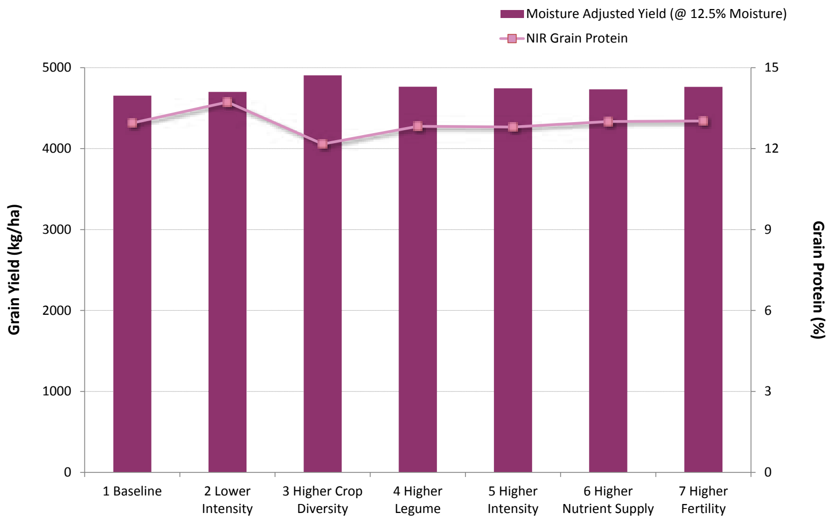


Figure 1. Yield and protein results for all treatments harvested in 2015

The site was selected in March 2015 and there was concern that deep ripping to apply deep phosphorus (P) would compromise planting opportunities for the 2015 winter crop. Consequently, deep P was applied immediately after post-harvest (early December) at a rate of 70 kg P/ha (i.e. 325 kg/ha of Granulock Z®) to all of the cropping treatments (1-7) to ensure P was not limiting in this trial in the near future. 35 t/ha of compost (25 t/ha dry weight) was also added to provide an extra 5 t/ha of organic carbon in treatment 7 prior to planting in 2015 and a further 40 t/ha (24 t/ha dry weight) was applied post-harvest.

Location:	Billa Billa
Previous crop:	Chickpea 2014
Crops (2015):	EGA Gregory$^{\mathrm{(D)}}$ Wheat & Bambatsi grass
Soil type:	Grey vertosol
In-crop rainfall:	140 mm
Fertiliser:	17 kg or 60k g/ha Granulock Z®

Implications for growers

It is too early to draw any conclusions after one year. However, the crop selection and planting rules developed with local agronomists to manage the proposed systems will see significant differences in the crops planted and their management in 2016 and future years.

David Lawrence, Andrew Erbacher and Tom Woods inspect the trial site

Acknowledgements

The team would like to thank the co-operator and Stuart Thorn (MCA Goondiwindi) their ongoing support of this experiment; along with many other growers and advisors who have contributed to the development of this project.

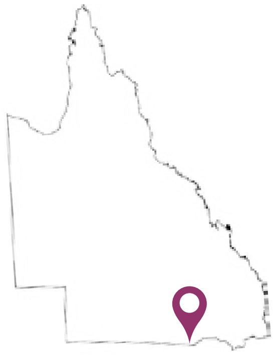
Thanks also to the Grains Research and Development Corporation and the Department of Agriculture and Fisheries for funding the project.

Field walk 2015

Trial details

Northern Farming Systems site - Mungindi

Rebecca Raymond
Department of Agriculture and Fisheries , Goondiwindi



Research Questions: *Can systems performance be improved by modifying farming systems in the northern grains region? | What are the trends that are expected in our farming systems? | How will these changes impact on the performance and status of our farming systems?*

Key findings

1. Too much nitrogen fertiliser can create a high biomass crop that may fail with limited moisture late in the season; producing lower yields with higher protein levels
2. Split applications of nitrogen need to be investigated for high nutrient systems in this region

Background

The project is undertaking a co-ordinated experimental program to examine how modifications to current farming systems affect the overall system performance. These modifications were chosen in consultation with growers, advisors and other researchers across the northern region. They are targeted to address apparent current and emerging challenges to farming systems.

The experiments will explore and deliver information on the following issues:

- Changes in farming systems that enable further increases in system efficiency
- Key issues or areas where current systems are under-performing
- Benchmarks for and gaps between current and potential system water use efficiency (not just the water use efficiency of individual crops)
- Benefits and costs of crop choices systems performance (water, nutrients, weeds, pests)
- Identify any possible future issues that will arise in response to changes in farming systems

The Mungindi farming area is based on winter cropping; mainly cereals (wheat and barley) and chickpeas, with limited summer cropping. The rainfall is variable with the highest rainfall months being late summer. The winter crops rely heavily on stored moisture. Most farms operate on a zero or minimum tillage system with a fairly set rotation of cereal/cereal/chickpea.

Local knowledge of nematodes is limited. However, some long-term cropping areas north of the border have significant numbers while nematode levels are typically lower to the south.

The trial site is located north west of Mungindi towards Thallon on a grey vertosol soil. The site has been cropped for 25 years, which the local cropping group considered to represent a large proportion of cropping in the region. The site has a large population of *Pratylenchus thornei* (nematodes) ranging from 6,000-26,000/kg of soil but no other soil constraints based on testing to date. The previous crop in the paddock was wheat (winter 2014) with standing stubble present and no major weed pressure. The area has been fenced to keep wildlife away from the plots.

Treatments

The site has six systems that were identified as priority for the area through consultation with farmers and advisers in the Mungindi Cropping Group.

1. **Baseline** - The baseline system was designed to represent a standard cropping system for the Mungindi region. The area is winter dominant with the three main crops being wheat, barley and chickpeas on a fairly set rotation of wheat/wheat/chickpea with an average of one crop per year.
2. **Baseline B** - Baseline B is currently treated the same as baseline and will allow the subsequent introduction of another treatment if another 'systems issue' arises.

3. **Lower crop intensity** - The low intensity system is designed to plant at a lower frequency when the profile is at least ¾ full. The rotation includes wheat/barley/chickpeas/sorghum and the option of a cover crop. Sorghum has been included as an option to enable a summer cropping opportunity.
4. **Higher crop diversity** - This system is investigating alternative crop options to help manage and reduce nematode populations, disease and herbicide resistance. The profitability of these alternative systems will be critical. A wider range of 'profitable' crops may enable growers to maintain soil health and sustainability as the age of their cropping lands increase. Crop options for this system include: wheat/barley, chickpeas, sorghum, maize, sunflowers, canola/mustard, field pea, faba bean and mungbeans.
5. **Higher legume** - The high legume system is focused on soil fertility and reducing the amount of nitrogen input required through fertiliser. It is required that one in every two crops is a legume and the suite of crops available for this treatment is: wheat/barley, chickpeas, faba beans and field peas all based on an average moisture trigger.
6. **Higher nutrient supply** - Nutrient supply is an area that is currently very conservative in the Mungindi region. Many growers put on very little fertiliser. This system is designed to identify if fertilising for a higher yield (90% of seasonal yield potential for nitrogen, and 100% replacement of phosphorus), is going to be financially beneficial in the long-term. Crop choice is determined by the baseline so that the two treatments can be compared.

Table 1. Details of the fertiliser treatments applied to each farming system

Treatment	Starter	N	Urea
Baseline	16 kg/ha	50 kg/ha	109 kg/ha
Baseline B	16 kg/ha	50 kg/ha	109 kg/ha
Low intensity	nil	nil	nil
High legume	16 kg/ha	50 kg/ha	109 kg/ha
Diverse crop options	7 kg/ha	nil	nil
High nutrient supply	56 kg/ha	125 kg/ha	273 kg/ha

Results

The first crops were planted in the winter of 2015. Four systems were planted to Gregory$^{\phi}$ wheat on 50 cm row spacing with a target population of 1,000,000plants/ha: baseline; baseline B; higher nutrient supply; and higher legume. The paddock had previously been treated with metsulfuron. This precluded chickpea being planted in the first year of the higher legume system and so it too, was planted to EGA Gregory$^{\phi}$ wheat. The higher nutrient supply treatment had noticeably thicker vegetation and was visibly a darker shade of green. However, the healthier looking crop did not translate into a higher yield when the season dried off (Figure 1).

The results in the baseline, baseline b and higher legume treatments were not significantly different at the P=0.055 level however, the higher nutrient supply treatment has a much higher protein level, higher screenings and a significantly lower yield that the other three. It appears that the high nitrogen input at sowing

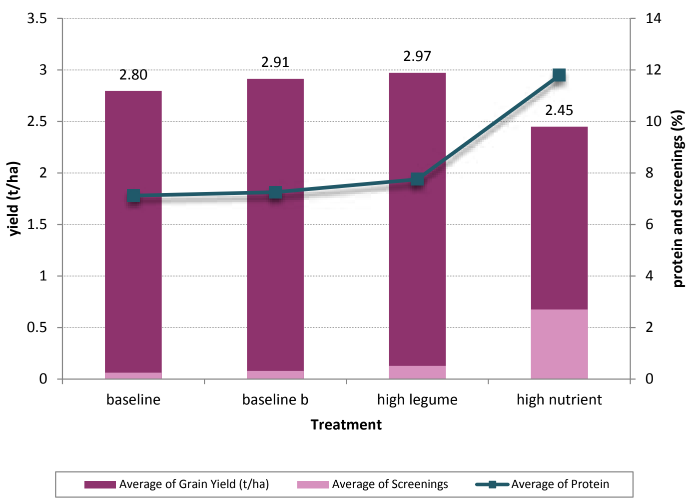


Figure 1. Results of four wheat treatments planted and harvested in 2015 at the Mungindi site (P=0.055)

used more water early in the season with its increased biomass, but was unable to finish well. The higher nutrient supply system ran out of moisture during grain fill, which resulted in a lower yield and much higher screenings than the other systems.

The yield of the three similar treatments was slightly higher than the average yield expectations from the APSIM model based on our measured starting moisture. However, protein levels were well below the expected protein level (11.5%) that was only achieved in the higher nutrient supply system. 'In-crop' or 'split' applications of nitrogen in seasons with good moisture levels may be needed to boost nitrogen supply and sustain higher yields (over 2.8 t/ha) by avoiding the significant yield losses that are indicated by grain protein levels below 8%.

The increased crop diversity system was planted to sunflowers in early September when plots reached their planting moisture trigger (150 mm plant available water) and minimum 10 degree soil temperatures. Sunflowers were selected as the site has high levels of nematodes and as a resistant crop, should assist in reducing nematode populations. The crop was managed according to best management practice and was sprayed for Rutherglen bug and helicoverpa during the season. The sunflower plots were fully netted to minimise 'bird damage' to these small and isolated sunflower plots.

Implications for growers

Growers in the Mungindi region currently don't use a large amount of fertiliser on their cereal crops for fear of growing too much biomass, as described above. However, the low protein levels in this 2015 trial indicate major yield losses due to nitrogen deficiency. Consequently, split applications of nitrogen in good seasons are worthy of consideration by growers and local investigation by research.

Acknowledgements

Many thanks must go to the trial co-operators; the Mungindi Cropping Group that has helped plan the trial; the Grains Research and Development Corporation and the Department of Agriculture and Fisheries for funding the project.

Trial details

Location:	Mungindi
Crop:	Wheat (winter 2015), sunflowers (spring 2015), sorghum (summer 2015/2016)
Soil type:	Grey vertosol
In-crop rainfall:	100 mm

Mick Brosnan and Andrew Earle inspect the trial site

Low intensity treatment in fallow versus Baseline treatment

Pathology research

The Regional Agronomy team has supported researchers at the University of Southern Queensland (USQ) by conducting pathology trials in both southern and central Queensland. This small research program has focused on two areas.

The first area explored the effectiveness, yield effects and economics of strategic fungicide applications to manage powdery mildew (*Podoshaera fusca*). Key findings were that strategic application of the fungicide Folicur 430EC® can reduce the rate of disease development and increase yield.

Powdery mildew trial at Hermitage Research Station showing treated Jade-AU⊕ plots and the susceptible variety Berkin, used as a inoculum source

Development of powdery mildew in an unsprayed plot of mungbeans

The second area of research explored the level of resistance of several current and experimental hybrid sorghum lines to charcoal rot (*Macrophomia phaseoloine*) and assessed whether the levels of resistance can be attributed to specific plant characteristics such as stay-green and maturity. Key findings indicate that there are significant differences between sorghum varieties; that high yielding varieties are more prone to colonisation and lodging associated with stalk rot pathogens; stay-green characteristics may provide some benefit; and lodging is not a reliable indicator for the presence of the disease.

Charcoal rot assessment in sorghum stems

Inoculating sorghum with charcoal rot

Powdery mildew control in mungbeans

Professor Malcolm Ryley[1], Dr Jodie White[1], Duncan Weir[2] and Rod O'Connor[2]
[1] University of Southern Queensland (USQ)
[2] Department of Agriculture and Fisheries (DAF)

Research Questions: *What is the most efficacious timing of fungicide sprays to manage powdery mildew in the mungbean cv. Jade-AU*$^{\Phi}$*? | What are the yield increases due to fungicide application in this pathogen-host combination?*

Key findings

1. Folicur 430EC® applied before or at the first sign of powdery mildew can reduce the rate of disease development in mungbean cv Jade-AU$^{\Phi}$ compared to no sprays
2. The 3-spray regime in which the first spray was applied before powdery mildew was observed in the trial resulted in the lowest final disease rating, the highest yield and the largest yield increase

Background

Powdery mildew of mungbean is caused by the fungus *Podosphaera fusca* and is found wherever the crop is grown. The disease is favoured by cooler conditions and is often widespread in late crops. Infected plants have a greyish-white powdery growth on the surface of leaves, stems and pods. It is first evident as small circular powdery spots on the lower leaves, rapidly covering the entire leaf and spreading to younger leaves up the plant (see photographs below).

Powdery mildew in mungbeans - early development (top) and well established

Significant yield losses can occur if the disease develops before or at flowering, particularly if the crop is under moisture stress. Late infections during pod fill can cause leaf drop but does not appear to seriously affect yield.

Losses in mungbean yield due to powdery mildew can range from 2.7% to 46% (most commonly 10-15%), depending on the variety, plant growth stage at time of appearance of powdery mildew and the rate of development of the disease.

Plant resistance and foliar fungicides are the only two viable options available for the management of powdery mildew. Most varieties are considered to be moderately susceptible, although cv. Crystal$^{\Phi}$ and cv. Jade-AU$^{\Phi}$ have slightly better resistance than the rest.

Although there are several formulations of sulfur that are either registered or under permit for management of the mungbean powdery mildew pathogen, the systemic fungicide tebuconazole currently under APVMA permit and sold as Folicur 430SC® or Hornet 500SC® is superior. Trials conducted over many seasons indicate that good control will be achieved if the first fungicide spray is applied at the first sign of powdery mildew on the lower leaves and another spray is applied two weeks later. Good control has also been achieved when the first spray is applied just prior to flowering even if powdery mildew is not present.

In 2015, trials were established in Emerald (Emerald Agricultural College), Warwick (Hermitage Research Station) and Dalby to determine the most efficacious timing of fungicide sprays to manage powdery mildew in mungbeans and quantify yield benefits in its control.

Treatments

Variety: mungbean cv. Jade-AU⁽ᴰ⁾

Trial design: randomized complete block, with one or four spreader rows of the powdery mildew susceptible cv. Berken between each plot (parallel to plot rows)

Replicates: 5

Plot size: 4 x 12m long rows, 0.75 m apart, two middle datum rows

Planting Dates :

- Dalby: 6 January 2015
- Hermitage Research Station: 19 January 2015
- Emerald Agricultural College: 12 January 2015

Fungicide treatment: 145 mL of Folicur 430EC® / ha (430 g ai/L of propiconazole), applied using LPG pressurised hand held 2 m boom spray, delivering 134 L water/ha at 5 kph (=8.6 s/12 m) and 3 kPa

1. Control, no fungicide application
2. spray 1 applied 5 weeks after emergence, spray 2 applied 14±2 days after first spray, spray 3 applied 14±2 days after second spray (total three sprays)
3. 1st spray applied at first sighting of a powdery mildew colony in the trial (total one spray)
4. 1st spray applied at first sighting of a powdery mildew colony in the trial, 2nd spray applied 14±2 days after first spray (total two sprays)
5. 1st spray applied when powdery mildew colonies reach 1/3 up canopy (total one spray)
6. 1st spray applied when powdery mildew colonies reach 1/3 up canopy, 2nd spray applied 14±2 days after first spray (total two sprays)

Results

Dalby

This trial was abandoned on 11 March 2015 following a crop inspection determining that powdery mildew had not established due to dry conditions.

Emerald Agricultural College

This trial wasn't harvest and abandoned due to lack of infection throughout the trial.

Hermitage Research Station

Powdery mildew development

Powdery mildew was first observed on 16 March 2015 (mean rating =3), so it was likely to have been present at least 7 days before (Figure 1). Powdery mildew developed rapidly in the control treatment (unsprayed) during the trial reaching a mean rating of 7.8 on 6 April 2015. The rate of disease development between 2-17 March 2015 was similar for all of the fungicide treatments except the prophylactic spray applied five weeks after emergence and before powdery mildew was observed. No disease developed over this period and the overall rate of disease development was lower than all other treatments, only reaching a mean rating of 3.4 on 6 April 2015 Treatments sprayed at the first sign of powdery mildew slowed the diseases development for seven days, after which the rate of development increased, particularly in the 1-spray treatment. Treatments sprayed when the disease was 1/3 up the canopy did not slow down the rate of development of powdery mildew compared to the control treatment.

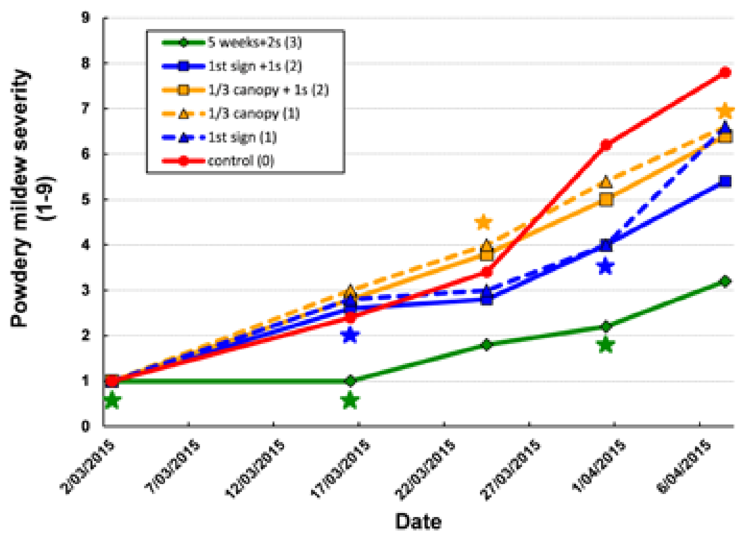


Figure 1. Powdery mildew development at Warwick

Table 1. Yield data and predicted profits of fungicide sprays from 2015 trial at Hermitage Research Station, Warwick

Treatment (no. sprays)	Yield (t/ha) and % increase [1]	$ value increase at $1200/t	$ value increase at $800 / t	$ Application costs [2]	$ Profit Trial yield $1200/t3	 Trial Yield $800/t[3]
5 wks + 2s	2.31 (9.5%)	240	160	60	180	100
1st sign + 1s	2.25 (6.6%)	168	112	40	128	72
1/3 canopy+1s	2.18 (3.3%)	84	56	40	44	16
1/3 canopy	2.13 (0.9%)	24	16	20	4	-4
1st sign	2.04 (-3.3%)	-84	-56	20	-104	-76
Unsprayed	2.11					

LSD (P=0.05)
[1] % increase over unsprayed treatment
[2] Application costs are a total of $20/ha/application for Folicur 430SC® at 145mL product/ha + ground rig application
[3] Calculations based on the trial treatment yields and a seed value of $1200/ha and $800/t

Yield and yield losses

All fungicide treatments except the single spray at the first sign of disease resulted in a higher yield than the unsprayed treatment (Table 1). Yield increases ranged from 0.9% for the single 1/3 canopy spray to 9.5% for the 3-spray treatment in which the first spray was applied before the appearance of powdery mildew. At $1200/t which was a common price in early 2015, the increases resulted in net profits of $4-$180/ha. However, using a more conservative price of $800/t, the yield increases resulted on profits/losses of -$4 to $100/ha.

Implications for growers

Early control of powdery mildew in mungbeans can lead to yield increases and economic returns.

Acknowledgements

Thanks to the Dalby grower, for his co-operation and assistance.

This trial was funded by the Grains Research and Development Corporation, the University of Southern Queensland and the Department of Agriculture and Fisheries.

Trial details

Trial One	
Location:	Hermitage Research Station, Warwick
Crop:	Mungbean cv. Jade-AU[⊕]
Soil type:	Cracking black vertosol
Trial Two	
Location:	Emerald Agricultural College
Crop:	Mungbean cv. Jade-AU⊕
Soil type:	Vertosol
Trial Three	
Location:	Dalby
Crop:	Mungbean cv. Jade-AU⊕
Soil type:	Vertosol

Charcoal rot in sorghum

Darren Aisthorpe[1], Jodie White[2], and Duncan Weir[1]
[1] Department of Agriculture and Fisheries (DAF)
[2] University of Southern Queensland (USQ)

Research Questions: *Determine the level of resistance of current and experimental hybrid sorghum lines to charcoal rot | Determine if infection levels can be attributed to specific plant characteristics such as staygreen and maturity*

Key findings

1. There are significant differences between varieties for lesion length and lodging
2. High yielding hybrids are more prone to colonisation and lodging associated with stalk rot pathogens
3. Staygreen lines may provide some benefit
4. Lodging is not a reliable indicator for the presents of *Macrophomina phaseolina* or *Fusarium* spp. in a crop

Background

Charcoal rot (*Macrophomina phaseolina*) is a major stalk rotting disease in sorghum which can infect the plant via the roots at almost any stage of growth. It can lead to significant levels of plant lodging and yield loss. The disease will often remain latent in the plant until post flowering at which point it develops rapidly. This occurs particularly when the plant is put under stress such as hot, dry conditions.

The fungus is widely spread throughout Australia infecting a large number of plant species. It survives in the soil as microsclerota and can survive in the soil and on stubble for four or more years. It can be identified in sorghum by splitting the stalk longitudinally. The characteristic black microsclerota can be seen in the vascular tissue and inside the rind of the stalk. The internal vascular tissue is grey or charcoal in colour and looks shredded, as opposed to healthy tissue which looks white and pithy.

There are no effective fungicides available to control the disease so management strategies must be considered. These include planting on adequate soil moisture, row spacing and plant populations, crop nutrition, crop rotations, varietal selection and application and timing of desiccation.

Little information is known about the genetic resistance to charcoal rot however characteristics such as staygreen, standability and drought resistance may reduce the development of the disease. There is some evidence that stay green lines may have a better tolerance to charcoal rot however the absence of lodging does not indicate the absence of the disease.

In conjunction with the university of Southern Queensland (USQ), trials were established in Emerald, Warwick (Hermitage Research Station) and Gunnedah. The trials were designed to explore the levels of resistance of several current and experimental hybrid sorghum lines to charcoal rot and if infection levels could be attributed to specific plant characteristics such as staygreen and maturity.

Treatments

Sixteen commercial and pre-commercial hybrid sorghum lines were tested using a randomised complete block design. 2 x 5 m rows for each treatment on 1 m row spacing.

Approximately two weeks post flowering, ten plants/variety/replicate were inoculated with *M. phaseolina* by inserting infected toothpicks into the stems at the second internode. Two plants/variety/replicate were also inoculated with a sterile toothpick (control) using the same process. Inoculations were conducted for each site.

At maturity, 10-14 days after application of a desiccant, stems from inoculated and control plants were destructively harvested, split longitudinally and assessed for disease.

Disease assessment

Disease assessment was based on length of internal lesion (mm). Isolations from plants (control and inoculated) were made to confirm infection and colonisation by *M. phaseolina*. Lodging was assessed on a per plot basis; the numbers of inoculated plants/plot were counted.

Results

The results presented are for the Emerald trial only. However, conclusions were developed from the amalgamation from all three trials.

Environmental conditions in Emerald were favourable for the development of the disease. High temperatures and moisture stress required the trial to be irrigated. Although plant establishment at Emerald was highly variable across varieties, the disease did establish itself, but no lodging was observed.

Significant differences in infection levels (measured as lesion length in the plant mm) were observed ($P \leq 0.05$) with the lowest average lesion lengths recorded by sorghum line 11 (18 mm) compared with the highest levels of colonisation in sorghum lines 7 & 9 (72 mm and 80 mm respectively) (Figure 1.)

No correlation was found between plant tiller number and average lesion length (R2=0.0059)

The Emerald trial had some significant differences in infection levels between lines. However, the overall level of infection and associated lodging was possibly constrained by low plant populations. A higher plant population may have increased the post flowering stress and subsequent infection levels and lodging.

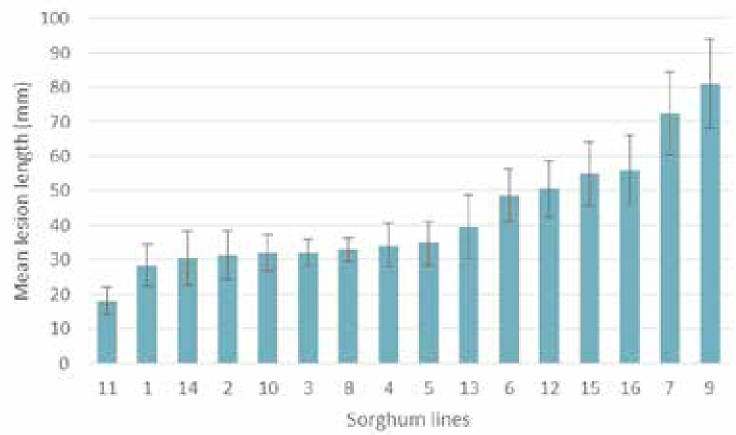


Figure 1. Mean lesion length (mm) of sorghum lines tested at Emerald site. Lesions were caused by co-infection of *Fusarium* sp. and *M. phaseolina*. Lines were significantly different at P≤0.05.

Charcoal rot infection (left four stems) and healthy sorghum (right four stems)

Conclusions and implications for growers

1. There are significant differences between varieties for lesion length and lodging.
2. Staygreen lines may provide some benefit to growers in seasons where the outlook for unfavourable weather conditions is high (hot dry conditions or 'hard finish')
3. Some non-staygreen lines can also perform well under conditions favourable for stalk rot infection, however, it is recommended that advice should be sort from seed suppliers or seed companies on specific lines prior to planting.
4. Lodging is not a reliable indicator of the presence of *Macrophomina phaseolina* in a crop. A standing crop can have a high incidence of pathogen resulting in a significant inoculum load for the next season.
5. Varietal selection is important when considering lodging potential, however, consideration of climatic conditions and agronomic factors such as plant population are also essential.

Acknowledgements

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Trial details

Location:	Emerald Research Facility and Hermitage Research Station, Warwick
Crop:	Sorghum
Soil type:	Cracking black / grey vertosol (Emerald) Cracking black vertosol (Warwick)

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Notes:

Queensland's Regional Research Agronomy Network conducts experiments that support agronomists and grain growers to make the best decisions for their own farms. The research summaries in this 'Trial Book' provide rigorous data for industry-wide solutions and relevant information to refine local practices.

For further information, please contact the relevant authors or the DAF Customer Service Centre on 13 25 23.