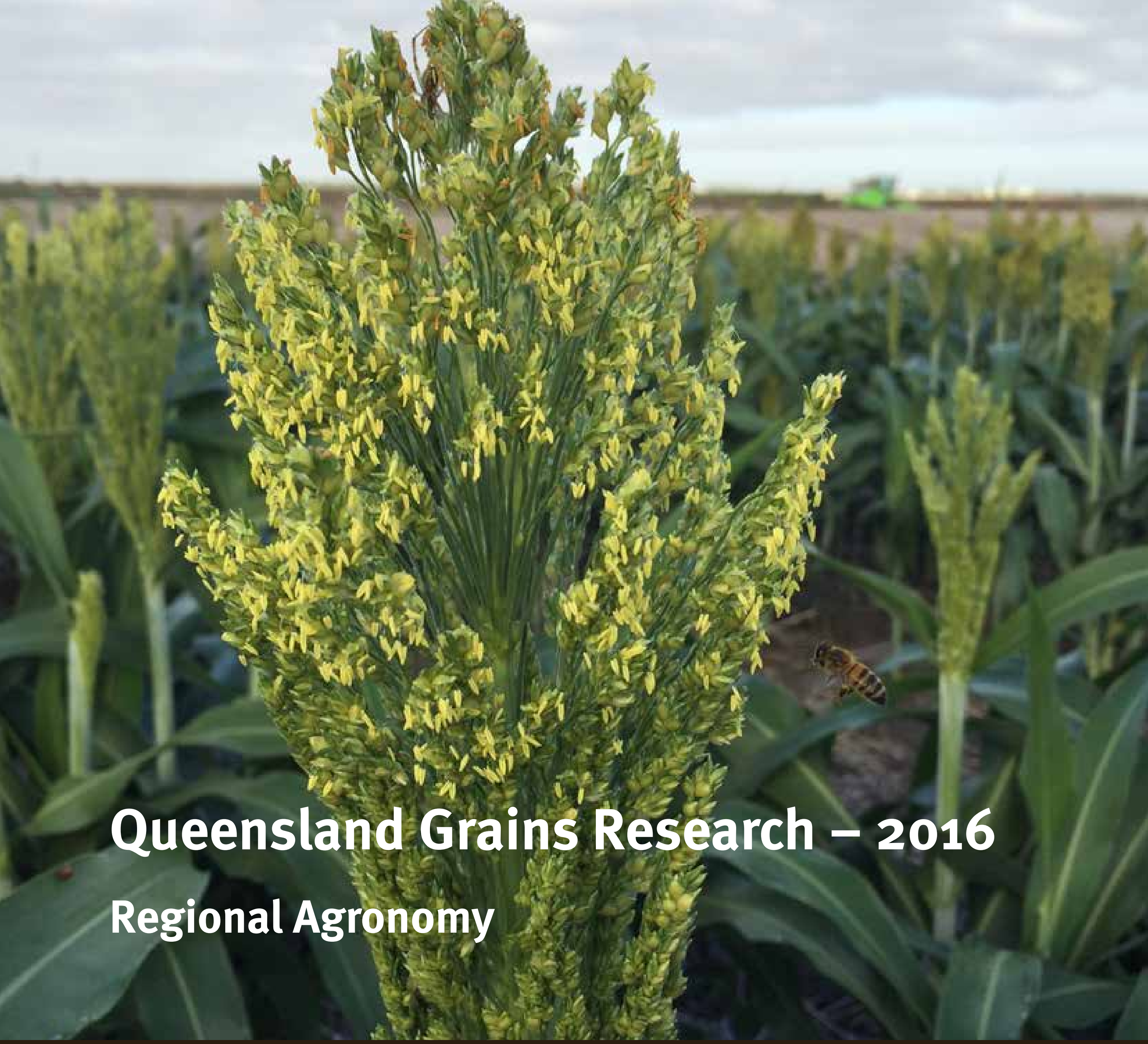
Queensland Grains Research – 2016

Regional Agronomy



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 is strongly committed to connecting grains research and development results, from a range of research organisations, to growers in regional Queensland. Our three regional agronomy teams based in Goondiwindi, Toowoomba and Emerald, undertake regional testing and validation of a broad range of contemporary grain production techniques and systems. Their purpose is to provide growers and advisors with best practice guidance to apply to their farming enterprises. Our regional agronomy teams are meeting the constant challenge of keeping up-to-date on grain production concepts and how those concepts can be tested regionally to show productive and economic benefits to the local industry.

This is the 2016 edition of Queensland Grains Research and it continues to communicate many of the key questions, underlying methodology and findings of the research achieved by our agronomists. Awareness of the regional research being carried out, accessibility of results and acknowledgement of the researchers who are leading the research, are key communication objectives of this edition. We reinforce our approach of conducting statistically sound trials through the close integration and support our regional agronomy team receives from the Department's biometry team of experts in trial design, analysis, efficient data capture and storage. This provides a framework of quality assurance to all components of our trial program and ensures rigor in our findings.

This research is co-funded by the Grains Research and Development Corporation and emphasises the importance of continuous investment throughout Australia's grain producing regions. We would also like to acknowledge the help of producers, advisers and agricultural supply chain businesses, such as seed companies and local suppliers, who have contributed to the success of these trials.

Garry Fullelove

General Manager, Crop and Food Science
Department of Agriculture and Fisheries, Queensland

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The Grains Research and Development Corporation (GRDC) plays a vital role investing in research, development and extension aimed at ensuring the enduring profitability of grain growers. The GRDC is committed to collaborating with specialist teams to investigate and develop best practice advice for growers that enhance productivity and profitability, and offers efficient, cost effective guidelines for the use of inputs, as well as the management and control of pest and disease threats. This GRDC investment, *Queensland Grains Research—2016 Regional Agronomy* publication, offers growers actionable and relevant information in response to ongoing and emerging on-farm management challenges.

Jan Edwards

Senior Regional Manager, North
Grains Research and Development Corporation

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We commend to you the information presented in this 2016 edition of Queensland Grains Research. We trust it is informative, challenging, and leads to on-farm productivity improvements. We welcome feedback as we continue to strive for continuous improvement in not only the research and development we undertake but in how we communicate the work and its results.

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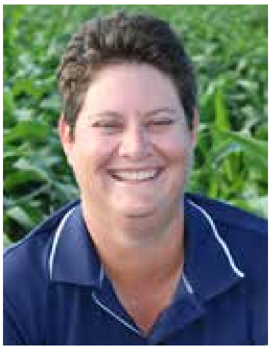
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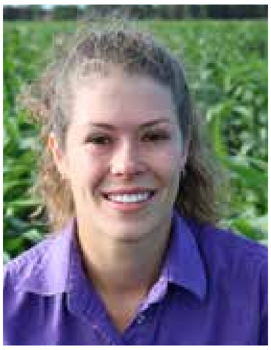
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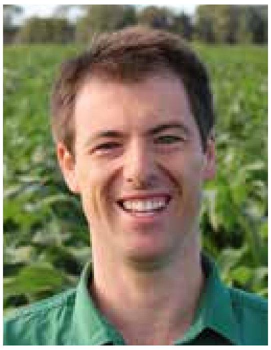
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Research Facilities

The regional research trials reported here would not have been possible without the support of dedicated Technical Officers and Operational Officers at the Department of Agriculture and Fisheries' 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 Queensland Agricultural Training College (Emerald) 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

The regional agronomy team's cereal agronomy work is a broad portfolio which encompasses both winter and summer agronomy trials, Australian Grain Technologies' phenology trials, Intergrain pre-breeding trials and National Variety Trials (NVT). In 2016, 22 trials, were undertaken and managed throughout the main grain growing regions of Queensland by agronomy teams based in Emerald, Toowoomba and Goondiwindi.

Variety Specific Agronomy Packages (VSAP)

VSAP is a co-funded research program between New South Wales Department of Primary Industries (NSW DPI) and the Grains Research and Development Corporation (GRDC). The Department of Agriculture and Fisheries (Queensland's component of the VSAP program), completed its second year of trials in 2016; 12 trials planted across seven different locations throughout central and southern Queensland.

The Queensland trial program consisted of three core trial designs:

1. Impact of time of sowing on phenology and physiology of 18 varieties of wheat.
2. Impact of population on the phenology and yield potential of six varieties of wheat.
3. Impact of nitrogen on the phenology and yield potential of five varieties of wheat.

Although there has been a considerable amount of agronomic research on these topics (populations, nitrogen responses, variety differences), breeding programs continue to develop new varieties with specific attributes, each with its own unique characteristics. Ongoing research through the VSAP program is showing that new varieties with specific attributes can respond differently than older varieties under similar production systems. These differences are leading to the development of new agronomic management packages under commercial production systems.

Analysis of the accumulated trials across Queensland and New South Wales is showing that there are consistent responses, particularly in relation to varieties and the effect N application can have on yield and quality. Varietal response to changes in population has remained reasonably consistent and generally the higher the population the better the potential yield result, particularly in a favourable season. However yield response does vary from site to site and variety to variety, so understanding varietal characteristics can greatly assist management decisions, particularly in a more marginal season or a late planting.

Harvesting wheat population trials at Emerald

A wheat trial at Allora in the early vegetative (tillering) stage

Time of Sowing (TOS) trials have shown distinct differences in variety responses in flowering and yield and in some regions, response curves have been very pronounced and significant. Understanding and managing the risk associated with frost has always been a critical management consideration. Data from TOS sites indicate that there may be greater risk of heat stress at the end of the season by holding on too long with the wrong maturities of wheat.

This was the final year for the VSAP work in this format. In 2017 the Queensland regional agronomy team will be working with NSW DPI as part of the new GRDC/NSW DPI research project focusing on winter grains agronomy right across Queensland and New South Wales.

Tactical agronomy for sorghum and maize

Summer cereal research is ongoing with agronomy trials on maize and sorghum being undertaken in Central and Southern Queensland in 2016 and again in 2017. Queensland Alliance for Agriculture Food Innovation (QAAFI) is the lead organisation of the GRDC funded project, UQ00075 Tactical Agronomy for Sorghum and Maize in the Northern Grains Region. Trials explored the effect of agronomic practices on crop performance across the grain growing region of Queensland.

Key variables in both the sorghum and corn trials planted in 2016 were population, row spacing and variety. Key outcomes from the trials showed that in Central Queensland, tillering for both sorghum and corn was significantly less and they were significantly quicker to mature when compared to crops in southern Queensland.

Climatic conditions played a big role in the trials performance, however both varietal and configuration differences were observed in both regions. This indicates that varietal selection and spacial placement may play a pivotal role in agronomic decisions into the future.

Maize: first silks starting to appear

Maize: measuring the effect on yield, quality and plant structure when manipulating hybrid variety, population and row spacing—Emerald

Darren Aisthorpe[1], Daniel Rodriguez[2], Katy Carroll[1] and James McLean[2]
[1]Department of Agriculture and Fisheries
[2]Queensland Alliance for Agriculture and Food Innovation

Research Questions: *What were the ideal agronomic configurations, for the season experienced, to maximise yield and optimise harvest index? What insights does performance difference between configurations provide for future crops?*

Key findings

1. In-crop rainfall, particularly during flowering and grain fill is essential to maximise yield.
2. For given conditions, the 1 m row spacing with 40,000 plants/ha population was the most consistent yielding treatment across all varieties.
3. Hybrid variation with respect to water scavenging ability in drier conditions was evident. Screening or measuring these genetic differences would be useful to better understand these traits when selecting future hybrids for planting in dryland conditions.

Background

Traditional summer rainfall reliability has diminished in recent years, so growers have become more reliant on stored moisture. To give greater security in crop production of both sorghum and maize in a dryland scenario, growers have widened row spacing and lowered target populations to try manage the limited water available in the profile. However, this approach has caused issues including weed management and capping of yield in higher rainfall years.

To assess what configurations optimise yield and harvest index, the Queensland Alliance for Agriculture and Food Innovation(QAFFI) team led by Daniel Rodriguez established a number of trials across Queensland as part of the UQ00075 - Tactical Agronomy for Sorghum and Maize in Queensland and Northern New South Wales, looking at the effect hybrid selection, population and row spacing can have on hybrid performance in a range of scenarios.

CRM- Comparative Relative Maturity is a maize maturity comparison unit from the United States based around days to maturity of the hybrid. 'Relative' is the key word, as the number may not have any direct correlation to local conditions.

However it does give a simple way to compare the maturity of various hybrids, as the larger the number, the longer the maturity.

What was done?

The trial was planted at the Queensland Agricultural Training College (QATC) on 18 February, 2016, on approximately 170 mm of water available to a depth of 1.2 m. The trial was planted using BOSS TX45 double disc parallelograms, and the seed metering unit was a traditional slotted cone.

The trial design was as follows:

- Hybrids included Pioneer Seeds P1467 (CRM114), P1414 (CRM114), P1070 (CRM110), and Pac Seeds Pac 606 IT (CRM114)
- Target populations of 20,000, 40,000 and 60,000 plants per hectare
- Row spacing configurations of 1 m and 1.5 m

A range of plant structure and phenology assessments were made during the growing period until the date of physiological maturity (which occurred for all treatments by 31 May; 104 days after sowing). Plant measurements included establishment counts, crop phenology, biomass cuts, final yield and yield components.

Determinations of plant emergence and phenology

After emergence the trial was thinned to the target population. A second plant count was conducted on 9 March with all target populations being achieved.

Dry matter at maturity and yield

A section of all plots were hand cut on 8 June, 2016. Primary stems, stem ears, tiller stems and tiller ears were separately collected, counted, and threshed for their contribution to yield. All plant material was then oven dried, and weighed.

Due to approximately 50 mm of rain falling between physiological maturity and the final harvest date, we were unable to determine residual values of plant available water (PAW) numbers to calculate a water use efficiency (WUE) for the treatments.

Results

Crop phenology (anthesis, silking dates and maturity)

Given similar CRM values for all four varieties, averaged across row spacing and plant population treatments P1414, P1070 and Pac606IT reached 50% anthesis and silking 49 days after emergence, while P1467 took 53 and 54 days respectively ($p<0.05$). However, it was interesting to observe that there was larger variability in flowering dates between hybrids across the three plant populations in the 1.5 m row spacing (Figure 1).

Biomass production and grain yield

Biomass production showed no statistical difference between the 40,000 plants/ha and 60,000 plants/ha populations. There was a significant difference ($p<0.05$) between the two higher populations and the 20,000 plants/ha population. This was particularly evident in the 1 m solid row spacing where the 20,000 plants/ha average population was 4.6 t/ha, and the 60,000 and 40,000 configurations yielded on average 6.1 t/ha and 7.1 t/ha, respectively. As an average across all treatments, P1467 and P1414 both averaged 5.8 t/ha and both produced their highest amount of biomass in the 40,000 plants/ha, 1 m spacing configuration.

Tiller numbers were exceptionally low across all treatments and hybrids with the average tiller count across the whole trial being 0.036 tillers per plant. The highest average tiller count for a given treatment combination was 0.11 tillers per plant for the 20,000 plants/ha population on 1.5 m spacing. The next was 0.063 tillers per plant for the 20,000 plants/ha population on the 1 m spacing. As a trend, tiller counts reduced to nothing as population increased beyond 40,000 plants/ha, irrespective of the row spacing.

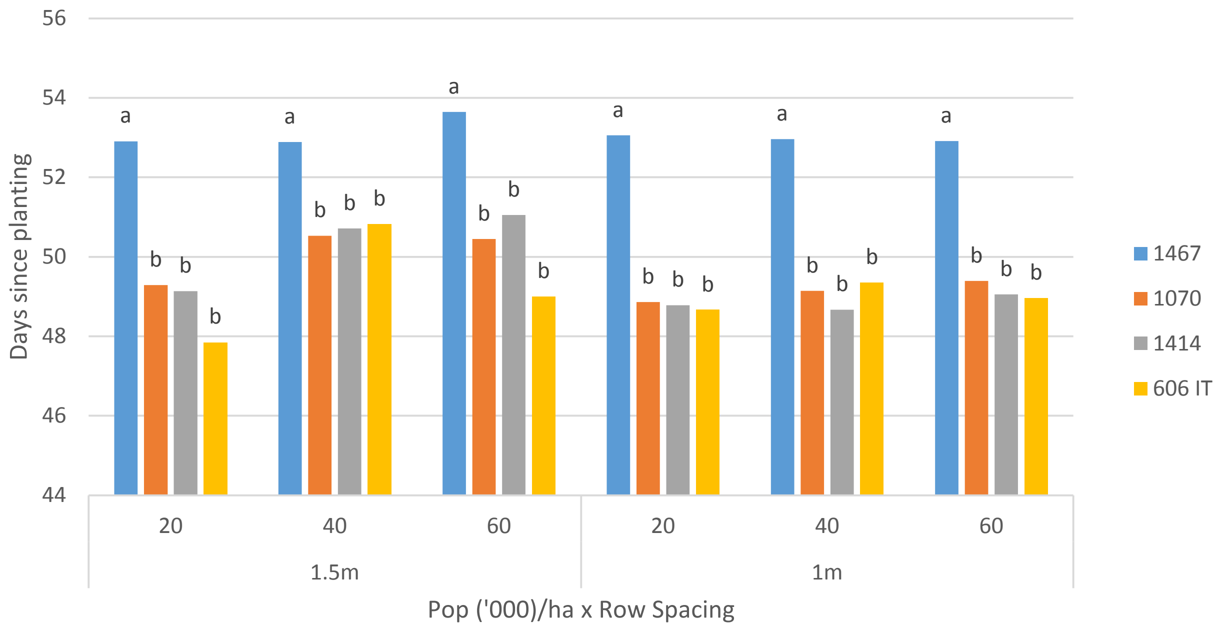

Figure 1. Days to 50% anther appearance across the treatments. Columns with different letters are significantly different to those with the same letter (P=0.05)

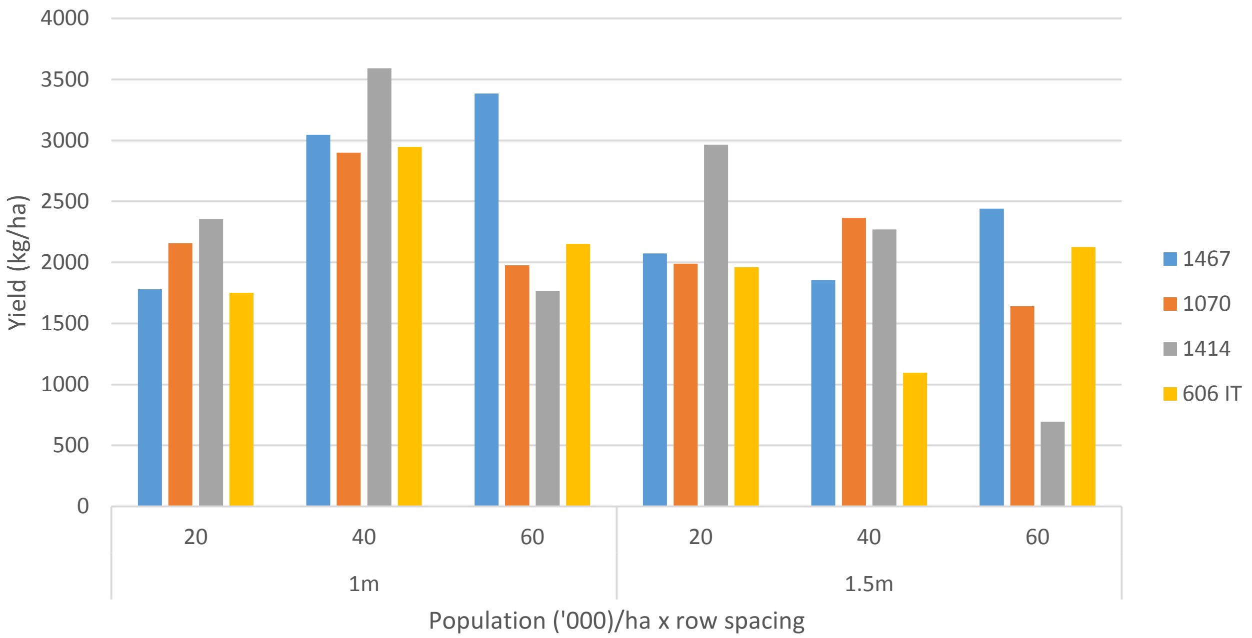

Figure 2. Average yield across all trial configuration. Due to variability in the trial there are no statistically different (P=0.05) results despite appearances

The trial had a very good start with adequate subsoil moisture, and a non-limiting nutrient situation to maximise yield potential. At the time of silking, there were some clear differences in visual biomass between hybrids and populations. However, due to no rain from mid-March onwards (pre-physiological maturity) all hybrids were affected.

There was no significant statistical differences in yield between treatments because of variability across the trial (Figure 2). Visually, P1467 appeared to hold on much longer than the other varieties in terms of leaf colour and appearance. However, the warm dry conditions with no in-crop rain during grain fill and a helicoverpa attack during early to mid-ear fill, led to some disappointing final yields.

Harvest index

Harvest index assesses how the different treatments converted total biomass produced into grain yield, the highest values of harvest index are around 50%. The higher the harvest index number, the better the conversion factor. In maize the harvest index is highly sensitive to stresses around flowering, so the dry warm conditions, particularly during the grain fill period, caused considerable variation and limited correlation between yield and harvest index for this trial (Table 1).

Table 1. Harvest index calculations based on total yield and total biomass collected for each treatment

Treatments	P1467	P1070	P1414	Pac 606 IT	Treat. avg.
1 m	0.44	0.41	0.40	0.40	0.41
20,000 plants/ha	0.39	0.46	0.43	0.45	0.43
40,000 plants/ha	0.42	0.46	0.44	0.42	0.44
60,000 plants/ha	0.53	0.33	0.31	0.34	0.37
1.5 m	0.38	0.42	0.39	0.39	0.39
20,000 plants/ha	0.39	0.42	0.48	0.43	0.43
40,000 plants/ha	0.37	0.43	0.40	0.27	0.37
60,000 plants/ha	0.37	0.40	0.21	0.44	0.37
Variety avg.	0.41	0.42	0.39	0.40	0.40

Implications for growers

A trial like this highlights the challenges maize faces in becoming established as a dryland crop in Central Queensland.

The last significant rainfall was received on 22 March (20 mm), with no additional rainfall or irrigation received after that date. Flowering/silking didn't start for another 2-3 weeks and average daily maximum temperatures throughout April and early May during the peak water usage period for the plants were consistently over 30°C. So despite planting on a reasonable to good profile of moisture with an excellent establishment, the crop failed to achieve the yields that the sorghum agronomy trial (page 7) achieved planted under almost identical conditions. It is known that maize is more sensitive to stresses than sorghum, particularly around the critical stages for grain number determination at flowering, and this season was a perfect example of that.

Manipulating planting time to ensure time of flowering and grain fill occurs during a wetter or cooler flowering period may play a role in optimising production. However, picking such a time is not easy, when other considerations such as frost risk for a later planting date or a lack of moisture in the profile for an early summer plant, both of which are significant issues in a dryland farming system.

Despite the hard finish the crop experienced, on average, across all varieties, the 40,000 plants/ha 1 m treatments all performed better than the lower 20,000 plants/ha population treatments. Equally it appears that the 1 m row spacing configuration performed far more reliably than the wider 1.5 m configuration in the dry conditions, with the possible exception of the 20,000 plants/ha 1.5 m (2.2 t/ha) which just managed to exceed 20,000 plants/ha 1 m (2 t/ha) for average grain yield. This trial has just been repeated in 2017 and the combined analysis of the two seasons of results will be reported in the next edition of this publication.

Acknowledgements

This research is funded by the Grains Research and Development Corporation and Queensland Alliance for Agriculture and Food Innovation. Thanks to the team working on Tactical Agronomy for Sorghum and Maize (UQ00075), Queensland Agricultural Training College (QATC) and Pacific Seeds.

Trial details

Location:	Field 5 Block 24 at QATC, Emerald
Crop:	Maize
Soil type:	A cracking, self-mulching, Grey Vertosol, in excess 1.5 m deep, with an estimated water holding capacity of approx. 230–240 mm of water, with no crop residue on the field. At the time of planting, there was 170 mm of water available to 120 cm of depth
In-crop rainfall:	121.8 mm of rainfall (Figure 3) (48.2 mm of which fell post physiological maturity) so effective rainfall would have been 74 mm + 25 mm irrigation on 18 March 2016 over the growing period
Fertiliser:	There was 180 kg/ha of nitrogen available in the soil at planting. In addition 30 kg/ha Granulock Z® was applied at planting and 150 kg/ha of nitrogen applied on 3 March 2016 in-crop when plants were at the 4-6 leaf stage

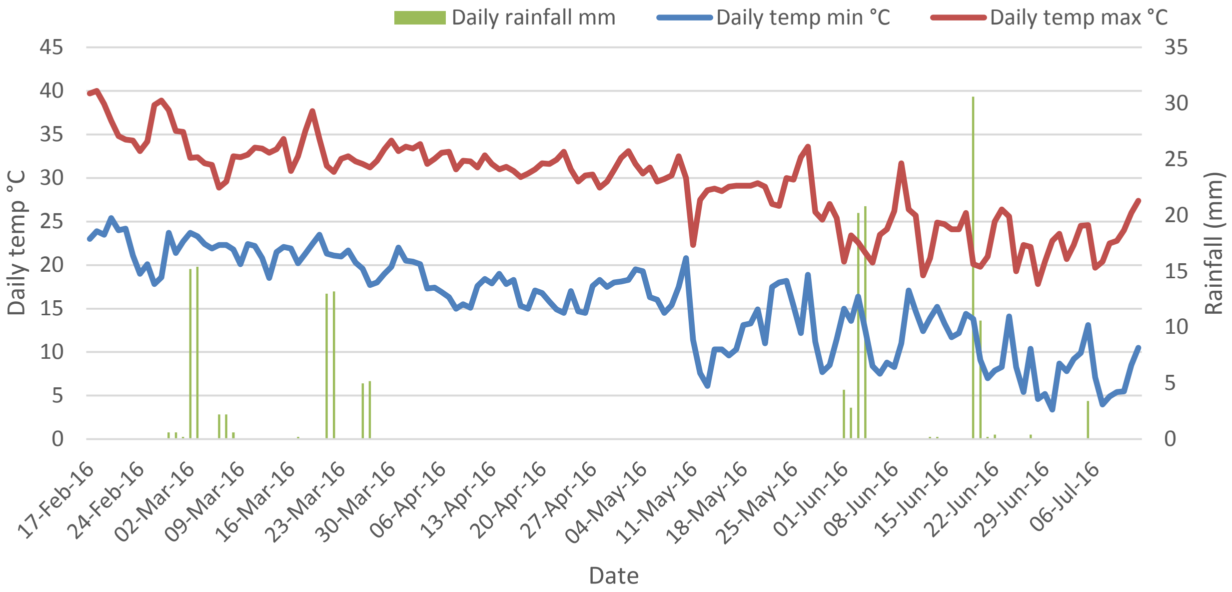

Figure 3. Weather data for trial site

Sorghum: measuring the effect on yield, quality and plant structure when manipulating hybrid variety, population and row spacing—Emerald

Darren Aisthorpe[1], Daniel Rodriguez[2], Katy Carroll[1] and James McLean[2]
[1]Department of Agriculture and Fisheries
[2]Queensland Alliance for Agriculture and Food Innovation

Research Questions: *What were the ideal agronomic configurations, for the season experienced, to maximise yield and optimise harvest index? What insights does performance difference between configurations provide with respect to future crops?*

Key findings

1. As population increases, seed size will always decrease relative to lower populations across all hybrid varieties.
2. Lower populations, and in particular lower in-row densities showed a strong correlation with higher tiller counts.
3. Solid plant, low population configurations of a low tillering variety may give larger grain size than skip row configurations with the same target population in tough, water stressed conditions.

Background

Traditional summer rainfall reliability has diminished in recent years, so growers have become more reliant on stored moisture, rather than in-crop rainfall. To give greater security in crop production of both sorghum and maize in a dryland scenario, growers have widened row spacing and lowered target populations to try to better manage the limited water available in the profile. However, this approach has caused issues also, including weed management and capping of yield in better years.

To assess what configurations optimise yield and harvest index, the Queensland Alliance for Agriculture and Food Innovation (QAAFI) team lead by Daniel Rodriguez established a number of trials across Queensland looking at the effect hybrid selection, plant population and row spacing can have on hybrid performance in a range of scenarios.

What was done?

The trial was planted at the Queensland Agricultural Training College— Emerald on 17 February, 2016, with approximately 200 mm of water available to a depth of 120 cm. The trial was planted using BOSS TX45 double disc parallelograms, and the seed metering unit was a traditional slotted cone, rather than a vacuum precision planter.

The trial design was as follows:

- Hybrids: MR-Buster, MR-Apollo, Pacific MR 43 and MR-Bazley
- Target populations: 40,000, 60,000 and 80,000 plants per hectare
- Row spacing configurations: 1 m 'solid' and 1 m 'skip row'

Establishment and populations were good, however spacing between plants was not as uniform as hoped. Plant counts were conducted on 2 March with all target populations being achieved or exceeded. MR-Apollo tended to achieve the highest average establishment populations, regardless of the target.

Head emergence and flowering dates were recorded for all treatments. The high population MR-Bazley treatments were the first to flower at around 49 days after planting and the low population MR-Apollo was the last to finish flowering at 54 days after planting.

A range of plant structure and phenology assessments were made during the growing period including; date of head emergence and flowering, final leaf numbers and date of physiological maturity (which had occurred for all treatments by 16 May; 89 days after sowing).

A section of all plots were hand cut on 7 and 8 June, 2016. Primary heads, tiller heads, primary stems and tiller stems were all collected. All plant material was then dried to remove moisture and weighed and/or threshed to calculate estimated yields and biomass production from the trial. Rain delayed the mechanical harvest of the plots until 12 July, no lodging was evident.

Unfortunately, due to the amount of rain which fell between physiological maturity and the final harvest date in 2016, we were unable to collect any meaningful harvest plant available water (PAW) numbers to calculate a water use efficiency (WUE) for the treatments.

Results

A considerable amount of data was collected from this trial, for the purpose of the QAFFI led Tactical Agronomy project, which is then compared to how southern trials performed. This report highlights some key observations from the Emerald trial.

Table 1. Average days to flowering across all populations and row spacing configurations

Hybrid	Mean	
MR - Apollo	53.51	a
PACIFIC MR 43	50.77	b
MR - Bazley	49.95	c
MR - Buster	49.72	c

Rows without a common letter in column 3 are significantly different (P=0.05)

MR-Apollo was the slowest of the hybrids to flower, followed by Pacific MR 43. There was no significant difference between MR-Bazley and MR-Buster in terms of days to flowering. Interestingly, there was a significant difference (P=0.05) in flowering date between the row spacing configurations, (Figure 1), with the single skip on average being quicker to flower than the 1 m solid layout, regardless of population.

Harvest observations

Biomass production was as expected with 80,000 plants per ha treatments averaging the highest amount of biomass per hectare (10.4 t/ha) followed by 60,000 (9.3 t/ha) followed by 40.000 (8.5 t/ha), each statistically different from the other.

Tiller counts did show a difference (P=0.05) between the number of tillers on MR-Apollo and Pacific MR 43 which was less than those observed on MR-Bazley and MR-Buster across all treatments. Tiller counts also consistently reduced as populations were increased with each population having a significant difference (P=0.005) from the other.

It is important to note that tiller numbers were generally low anyway, with 40,000 solid treatments having the highest average tiller count of 0.4 tillers per plant and the highest row density of 80,000 single skip only averaging 0.14 tillers per plant across treatments.

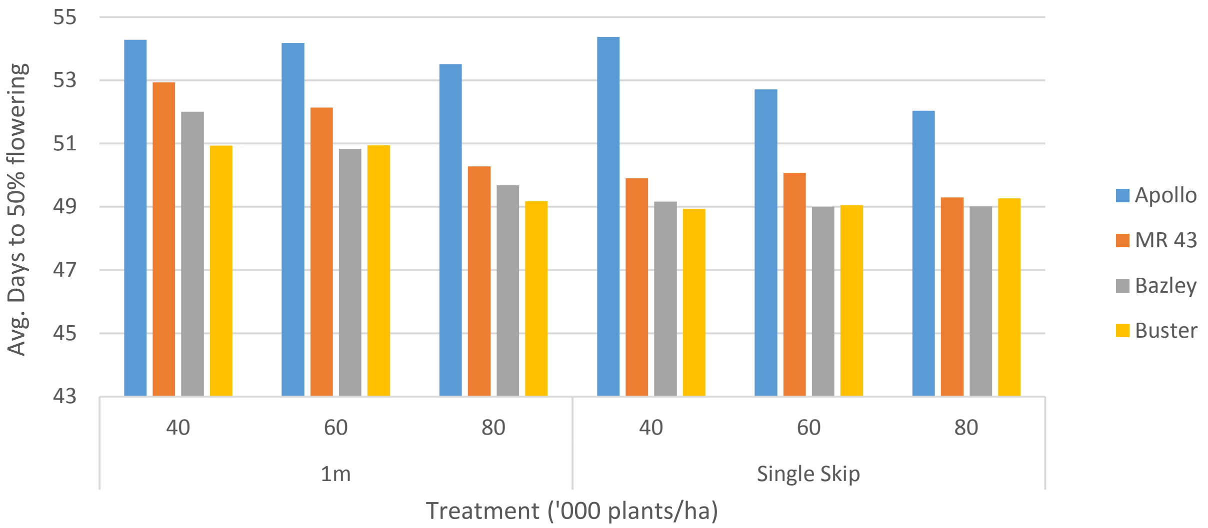

Figure 1. Average days to 50% flowering across row spacing, populations and varieties

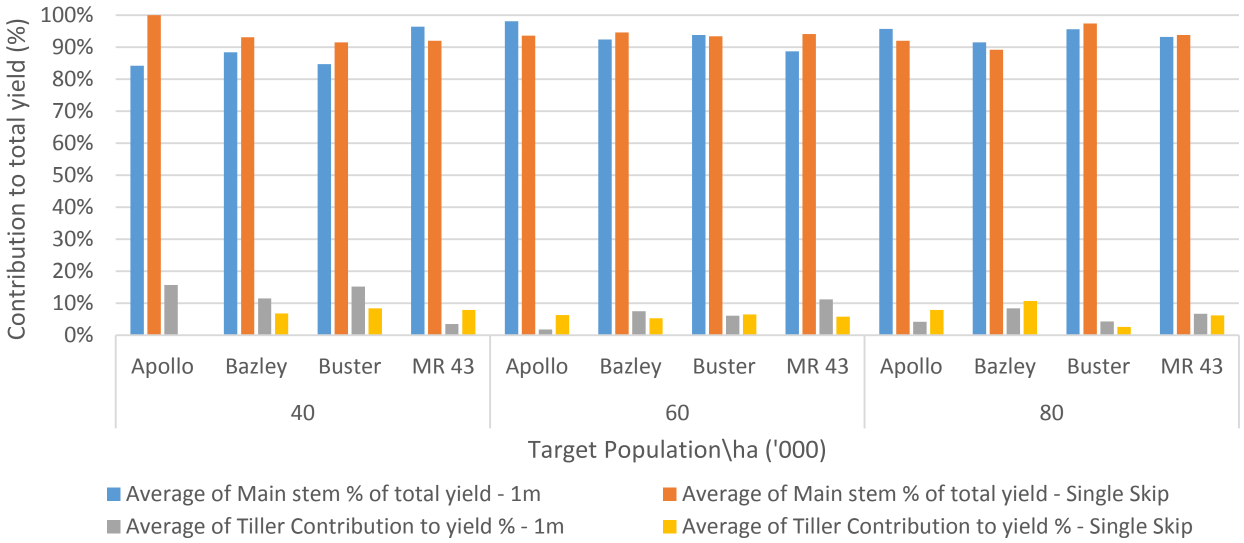

Figure 2. Comparison of yield contribution between tillers and the main stem across all treatments

The low tiller counts correlate with the contribution of tillers to total average yield of each treatment. Despite having reasonable moisture, at least until grain fill, there was only a small percentage of the yield from any treatment which came from the tillers in this particular trial. Even varieties which tend to have a higher tillering ability such as MR-Buster still only had at most a 15% contribution to yield, at the lowest population density of 40,000 solid.

There were no statistically significant changes to yield contribution no matter what population or row spacing configuration was used in this trial, although there was a strong trend indicating that lower population and row density treatments (solid treatments) had higher tiller counts than higher population or density treatments.

Grain weight was affected significantly (p=0.05) with both the main stem and the tiller stem; 40,000 populations always had larger seed (30.6 mg/grain) than 60,000 populations (28.7 mg/grain), which were always larger than 80,000 populations (27.5 mg/grain). MR-Apollo (30.1 mg/grain) and MR-Buster (29.4) were the significantly larger seeded varieties (p=0.05) in this trial on the main stem although statistically there was no significant difference between them. Tiller heads were similarly affected, reducing from 29.7 to 27 mg/grain as population increased (p=0.05) from 40,000 to 60,000, however there no difference statistically between the 60,000 and 80,000 grain weights on the tillers.

Yield

The trial had a very good start with good subsoil moisture, and a non-limiting nutrient situation to maximise yield potential. However, a hot dry finish (pre-physiological maturity) did test the treatments and despite the high population 80,000 solid treatment on average coming out on top, there was no statistical difference between it and the 60,000 treatment nor was there a statistical difference between varieties across all treatments.

Table 2. Significant treatment affects observed on yield

Target population ('000)/ha	Yield (kg/ha)		Target population ('000)/ha and Spacing	Yield (kg/ha)	
80	5107	a	80 solid	5570	a
60	5048	a	60 solid	5371	ab
40	4239	b	60 single skip	4725	bc
			80 single skip	4645	bc
			40 solid	4316	cd
			40 single skip	4161	d

Rows with different letters are significantly different to other rows (p=0.05)

Harvest index

Harvest index assesses the efficiency of biomass to convert to grain. The higher the harvest index number, the better the conversion factor. Table 3 gives a breakdown of all the treatments and their harvest index, and also gives an average harvest index number for all population treatments and all varietal treatments.

Table 3. Harvest index ratio for all treatments and varieties

Treatments	MR-Apollo	Pacific MR 43	MR-Buster	MR-Bazley	Treat. avg.
1 m solid					
40,000	0.54	0.48	0.46	0.45	0.48
60,000	0.47	0.59	0.57	0.55	0.54
80,000	0.48	0.47	0.52	0.57	0.51
Single skip					
40,000	0.51	0.47	0.55	0.53	0.51
60,000	0.52	0.50	0.57	0.55	0.54
80,000	0.45	0.43	0.46	0.55	0.47
Variety average	0.49	0.49	0.52	0.54	0.51

The overall average harvest index for the trial was 0.51, however, there were treatments within the trial which were far more efficient than others. The two quicker varieties, MR-Bazley and MR-Buster, had the higher harvest index for this scenario and when analysing the treatment summary it was clear that the 60,000 treatment was the most efficient for both row spacing configurations. However, in the solid planting configuration, 80,000 was more efficient than 40,000. Interestingly, this is reversed in the skip row configurations.

Implications for growers

It was disappointing that we were unable to get usable harvest water numbers before all the rain that was received just before harvest. General observations match with the harvest index numbers which indicate that despite having good starting water profile, the crop set up for a big yield, but the lack of good follow-up rain at or before flowering and grain fill meant that particularly the high population treatments were not able to finish the job.

At a broader level, what has been highlighted is the need to understand hybrid attributes to better match with seasonal conditions to achieve market specifications. For example, in a tough year with a lower profile of water, MR-Apollo at 40,000 solid may give a higher harvest index, larger seed, and minimal tillers, however that configuration will never maximise yield, if good in-crop rain comes, when compared to a higher population and or a higher tillering variety.

Another point of interest was the effect of in-row density on grain size and yield. It was apparent, despite very similar populations, that there was a drop (although not statistically significant) in yield and a reduction in grain size, compared to the 1 m solid equivalent at all population levels. This raises the question that if technology allowed, what effect would narrower spacing (50 cm), precision spaced seed have at the same density per hectare. Would it further improve seed size and increase weed competition as well? Could we plant higher populations of low or non-tillering varieties and still maintain larger seed size without compromising yield potential?

Acknowledgements

The Grains Research and Development Corporation and Queensland Alliance for Agriculture and Food Innovation, and the team working on Tactical Agronomy for Sorghum and Maize (UQ00075), Queensland Agricultural Training College (QATC), and Pacific Seeds.

Trial details

Location:	Field 5 Block 7 at QATC, Emerald
Crop:	Sorghum
Soil type:	A cracking, self-mulching, Grey Vertosol, in excess 1.5 m deep, with an estimated water holding capacity of approximately 230–240 mm
In-crop rainfall:	121.8 mm of rainfall (48.2 mm of which fell post physiological maturity) so effective rainfall would have been 74 mm + 25 mm irrigation on the 18/03/2016 over the growing period
Fertiliser:	There was 160 kg/ha of nitrogen available in the soil at planting. In addition 30 kg/ha Granulock Z® was applied at planting and 150 kg/ha of nitrogen applied on 3/03/2016 in-crop when the plants were at the 4-6 leaf stage

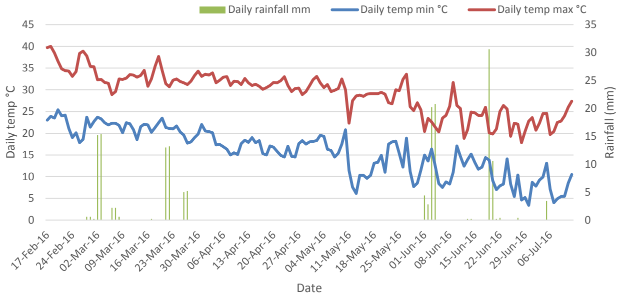

Figure 3. Summary of weather data collected on site throughout the duration of the trial

Wheat: the effects of different planting dates on yield and plant physiology across different varieties—Emerald

Darren Aisthorpe
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?*

Key findings

1. Time of sowing had the greater effect on yield rather than variety.
2. Heat at flowering and accumulated solar radiation do have a significant effect on yield potential.
3. Select a varietal maturity and disease package which best suits your planting situation.

Background

Optimising planting date for any wheat variety is a critical factor in achieving maximum yield potential. There is a wide range of slow, medium and quick maturity varieties available on the market for growers to select from. Each variety comes with their own unique agronomic advantages and disadvantages across a range of agronomic factors such as disease tolerance, physiological attributes, harvestability, and milling qualities of the delivered grain.

Understanding how varieties perform under a range of environmental conditions and planting dates will allow growers to better balance the regional risks of frost and heat stress related yield loss. The trial in Emerald was designed to better understand how time of sowing affects the phenology and potential yield of a range of varieties within the Central Queensland (CQ) region.

What was done?

The trial was planted at the Queensland Agricultural Training College (QATC)—Emerald, using a cone planter equipped with Boss TX 45 parallelograms with double disc openers on 50 cm row spacings, with a target population of 1,000,000 plants per hectare.

Table 1. Sowing dates of each time of sowing event and plant available water at sowing down to 90 cm

Time of Sowing (TOS)	Date planted	Plant available water (PAW) at sowing (mm)
TOS 1	16/03/2016	158
TOS 2	13/04/2016	159
TOS 3	11/05/2016	147
TOS 4	15/06/2016	172

The eighteen varieties in order of maturity from slowest to quickest (2017 Queensland wheat varieties guide) were:

EGA Eaglehawkᶲ, Strzeleckiᶲ, EGA Gregoryᶲ, LongReach Lancerᶲ, EGA Burkeᶲ, Sunguardᶲ, Baxterᶲ, LongReach Gauntletᶲ, Mitchᶲ, Kennedyᶲ, Vikingᶲ, LongReach Crusaderᶲ, Elmore CL Plusᶲ, Suntopᶲ, LongReach Spitfireᶲ, Sunmateᶲ, Condoᶲ and LongReach Dartᶲ.

In-crop measurements included establishment counts, head emergence, 50% anthesis and head height assessment.

Due to the wide range of maturities and planting dates, plot harvest took place as soon as possible after plots ripened. This resulted in ten separate harvest events between 6 July and 27 October. Some of the early plots were hand cut because of adverse weather conditions during July 2016. All grain was weighed and tested for moisture, protein, screenings, test-weights and seed size.

Starting and finishing gravimetrics were taken on all Suntop$^{\phi}$ treatments to get a measure of water use efficiency (WUE) differences for different Time of Sowings (TOS).

Results

Seed germinations were tested and seed weights measured of each variety prior to planting. Seed germination percentage ranged from 75% to 97% (average 89%) and seed size ranged from 21,700 seeds/kg to 40,650 seeds/kg (average 27,850 seeds/kg). This translated to an average planting rate of 48.8 kg/ha (36 kg/ha to 63 kg/ha).

Three days after planting TOS 1, temperatures reached 40°C, which made conditions difficult for emerging seedlings, and population counts reflected this. Equally for TOS 4, in excess of 40 mm of rain fell reasonably quickly just after planting which again caused surface sealing and crusting, once again limiting establishment (Figure 1).

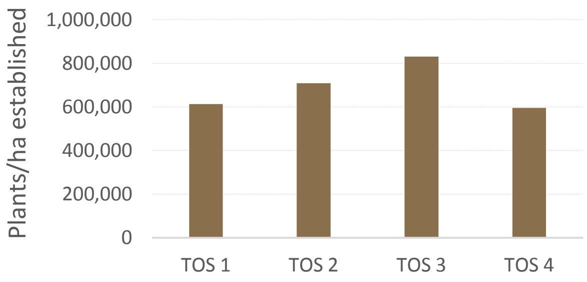

Figure 1. Average plants established across all varieties for each time of sowing. TOS 1 and 4 were both significantly affected by weather variables around their individual sowing dates

TOS 4 struggling to emerge through crusting after 40 mm of rain

Both variety and time of sowing had a significant effect on days to flowering (50% anthesis) at the Emerald site (Figure 2 and Appendix). Within a time of sowing treatment, the gap between the first variety to flower and the last to flower changed considerably between sowing dates. Generally the slower varieties tended to have slightly less variation in days to flowering in this year's trial between TOS dates, although still significant, while the medium and quicker maturity varieties showed greater variation in days to flowering across the four sowing dates.

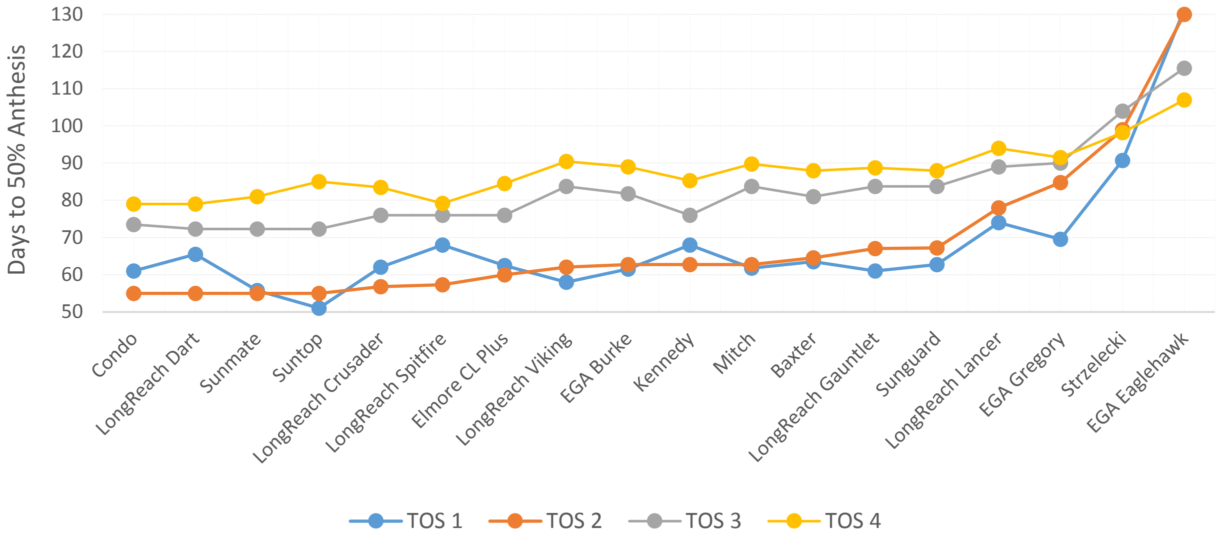

Figure 2. Average days to flowering (50% anthesis) for all varieties across all TOS dates. Least Significant Difference (LSD) for varieties with a TOS is 3.57 days, LDS for different TOS dates is 3.6 days; (P=0.05)

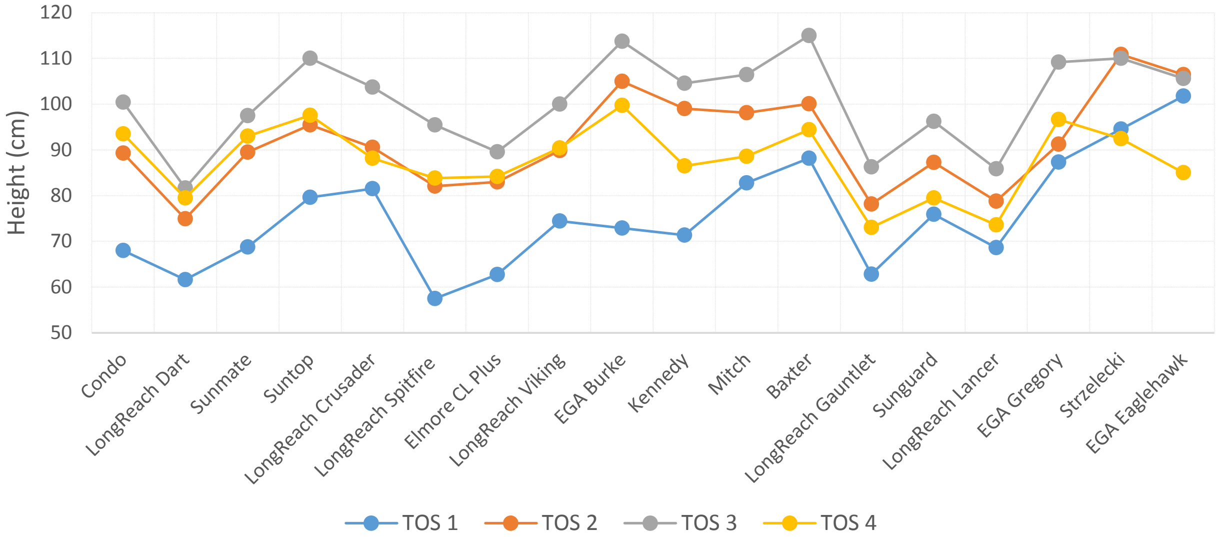

Figure 3. Plant height was measured at grain fill for all varieties and TOS plantings. The graph above illustrates the variation in plant height between TOS dates and varieties. LSD with a TOS was 3.89 cm while LSD between TOS dates was 4.83 cm

Plant height, and as such biomass production did vary significantly (Figure 3) both between varieties and TOS events for most varieties. Varieties such as LongReach Spitfire[⌽] and EGA Burke[⌽] showed some of the greatest variation in height between planting times, while LongReach Dart[⌽] or Longreach Lancer[⌽] showed the least variation.

There was a trend that yield increased in line with plant height for TOS 1. This was related to the quick maturing varieties, producing a very limited number of tillers and matured very quickly in the hot conditions. The slower varieties however hung on longer, produced more tillers and biomass, to flower in cooler conditions and generally tolerated the early hot conditions better than the quicker, earlier flowering varieties.

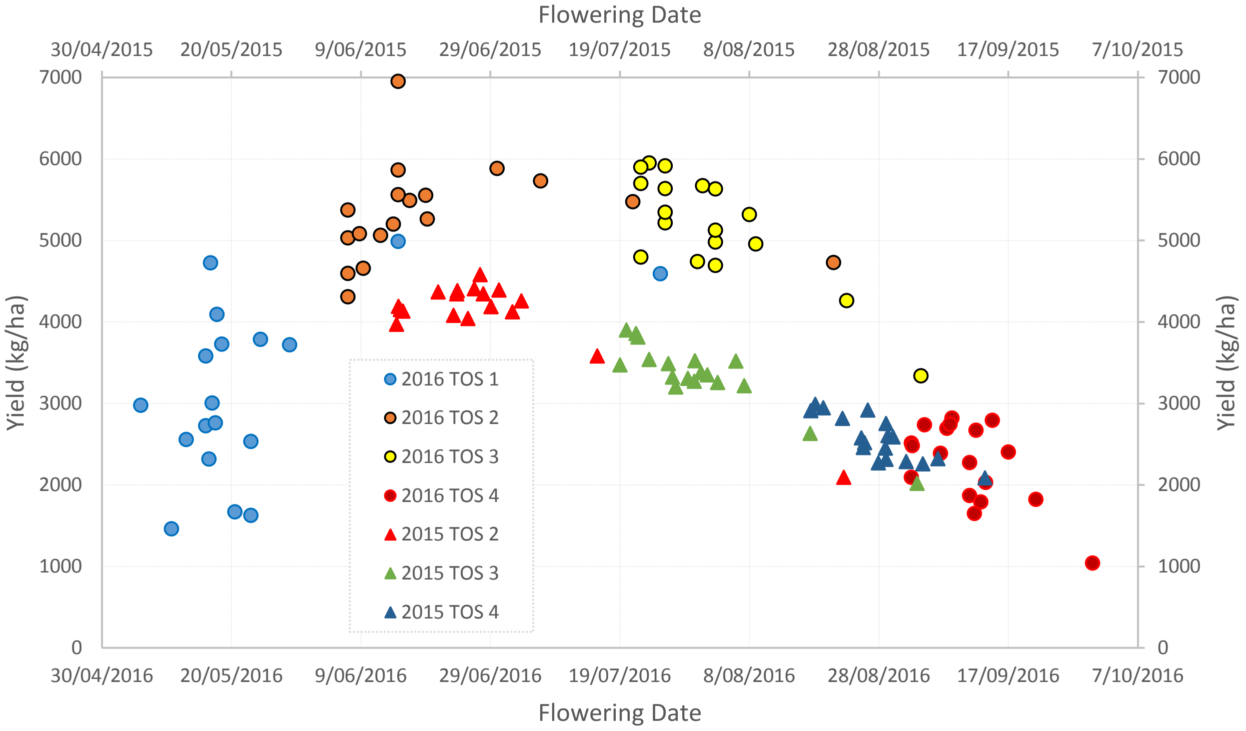

Figure 4. Effect of sowing date on yield. 18 varieties shown for each sowing date, LSD within a time of sowing (2016) was 394 kg, LSD between each sowing date (2016) was 411 kg; (P=0.05). For the 2015 yields, LSD within a TOS was 361.7 kg while LSD between 2015 TOS events was 590 kg; (P=0.05)

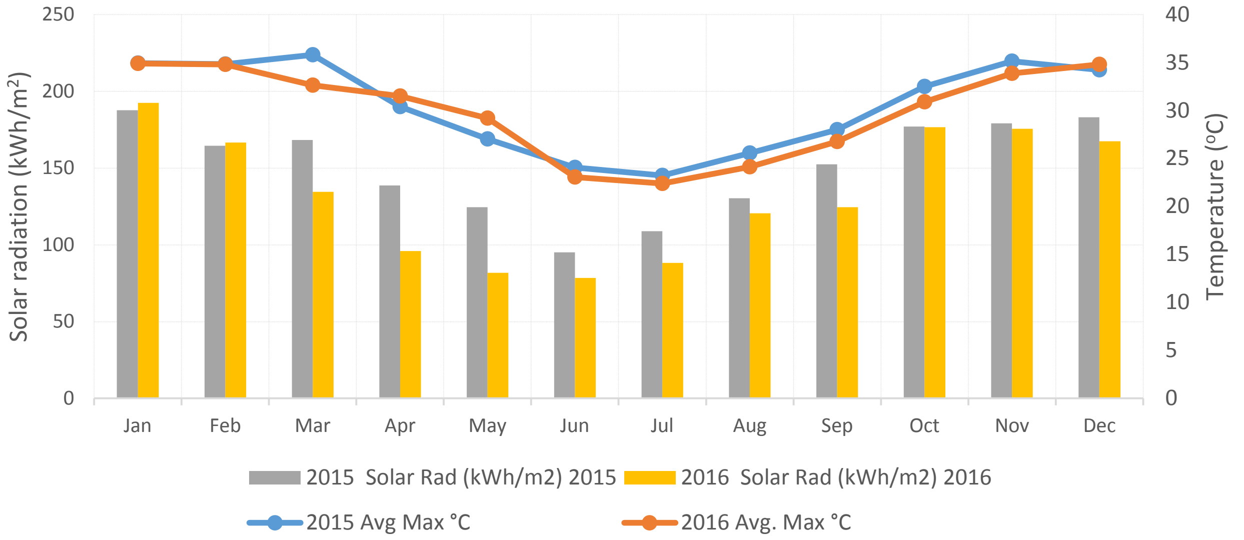

Figure 5. Monthly accumulated solar radiation (kWh/m²) and average daily maximum temperatures (°C) for 2015 and 2016. While there was minimal average temperature variation across the two years, it is interesting to note the variation in accumulated solar radiation

Yield

Yield variation across the varieties and across the TOS events was significant. Sowing date was the most significant factor that drove yield variation (Figure 4 and Appendix).

Despite a milder season and more in-crop rain than 2015, starting plant available water (PAW) was similar and there wasn't a big difference in maximum daily temperatures between the two years (Figure 5), however there was a difference in solar radiation.

When you compare flowering temperature and final yield for both years (Figure 6), 2015 had a stronger trend than was seen in 2016 towards higher yields at cooler maximum daytime temperatures. Both however support that cooler temperatures at flowering and grain fill do give higher yields.

The difference in accumulated monthly solar radiation, particularly between February and August also appeared to have an influence. A comparison of accumulated solar radiation (kWh/m²) from sowing date to 50% anthesis (Figure 7) shows a trend toward higher yields with lower solar radiation accumulation.

Varietal performance varied according to planting dates, with certain maturities performing better or worse depending on the planting window (Figure 8). The longer season varieties perform better when planted earlier and quicker varieties will outperform them in

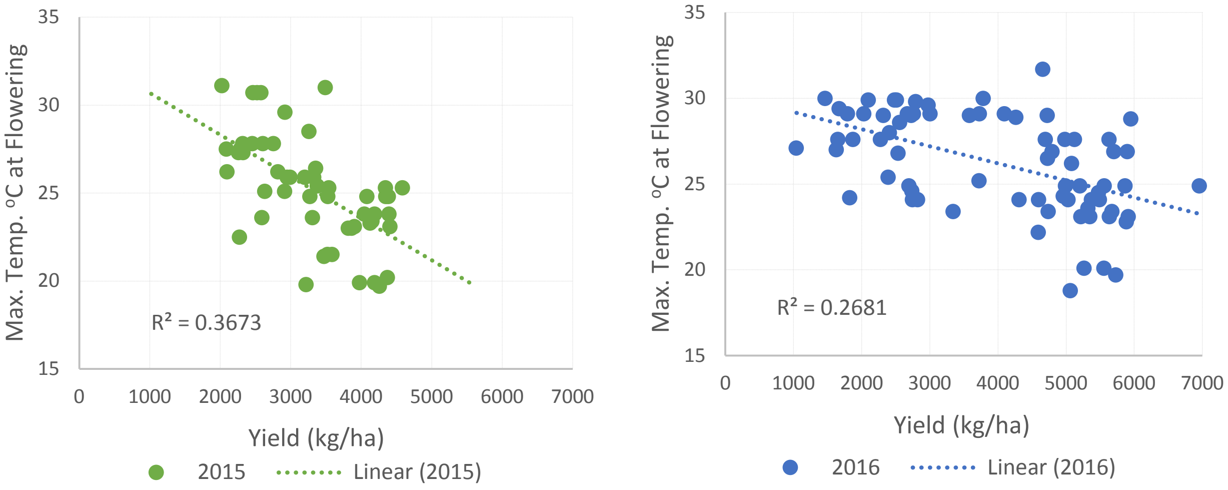

Figure 6. Interaction between temperature at flowering and final yield for 2015 and 2016 trials. As expected, the highest yields were achieved during the cooler flowering periods, generally within TOS 2 or early TOS 3

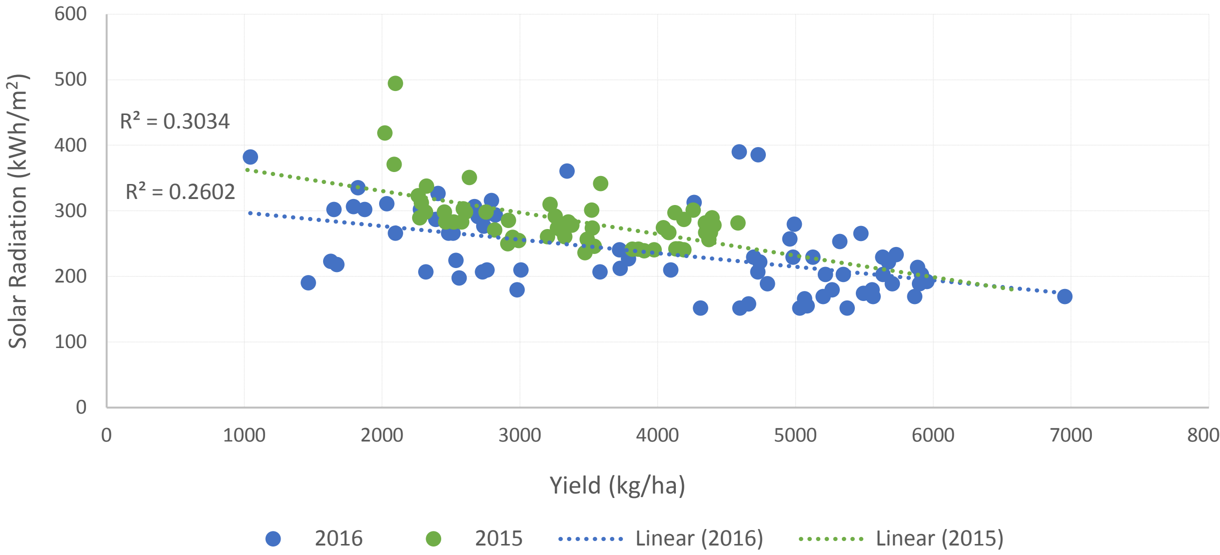

Figure 7. Interaction between solar radiation and yield for 2015 and 2016 trials, which indicates the lower solar radiation to flowering, the higher potential yield. All treatments that exceeded 4 t/ha were under 300 (kWh/m²) and the highest of all yielding treatments were sub 250 (kWh/m²)

later planting dates. In TOS 1 anything with a similar maturity to Mitch⦶ or slower performed significantly better than the quicker varieties, whereas in TOS 4 the reverse was true.

Grain qualities

The protein levels indicate that nitrogen was not limiting yield within the trial (Figure 9). As yields increased between TOS dates, protein levels did drop, however TOS 4 did not increase in protein as much as expected despite much lower yields compared to TOS 2 and 3.

Screenings for the first two TOS dates were excellent with all varieties comfortably slipping in below the 5% receival standard (Figure 10). In TOS 3 some slow varieties did slip over the 5% threshold, indicating heat stress at the end. By TOS 4, none of the varieties were able to achieve the 5% screenings level. These results correlate well with weather conditions during grain fill. The last significant rain before harvest was received in mid-July, a week before TOS 3 began flowering, and nearly seven weeks before the first of the varieties from TOS 4 began flowering. TOS 4 also suffered temperatures climbing quickly during grainfill.

Implications for growers

If a mid to late March planting window presents, only long season varieties should be considered. By delaying planting to mid-April, a wider range of medium and quicker maturing varieties can be used and additional frost management strategies could be implemented. Those with

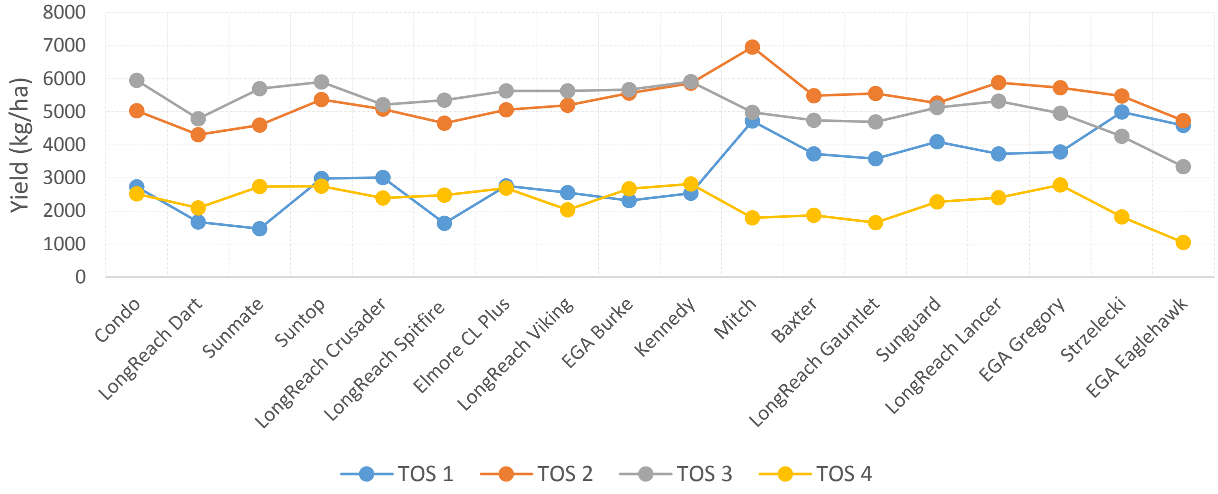

Figure 8. Varietal yield (kg/ha) across all four times of sowing for all 18 varieties used. LSD for same TOS is 394 kg, LSD between TOS dates is 411 kg; (p=0.05)

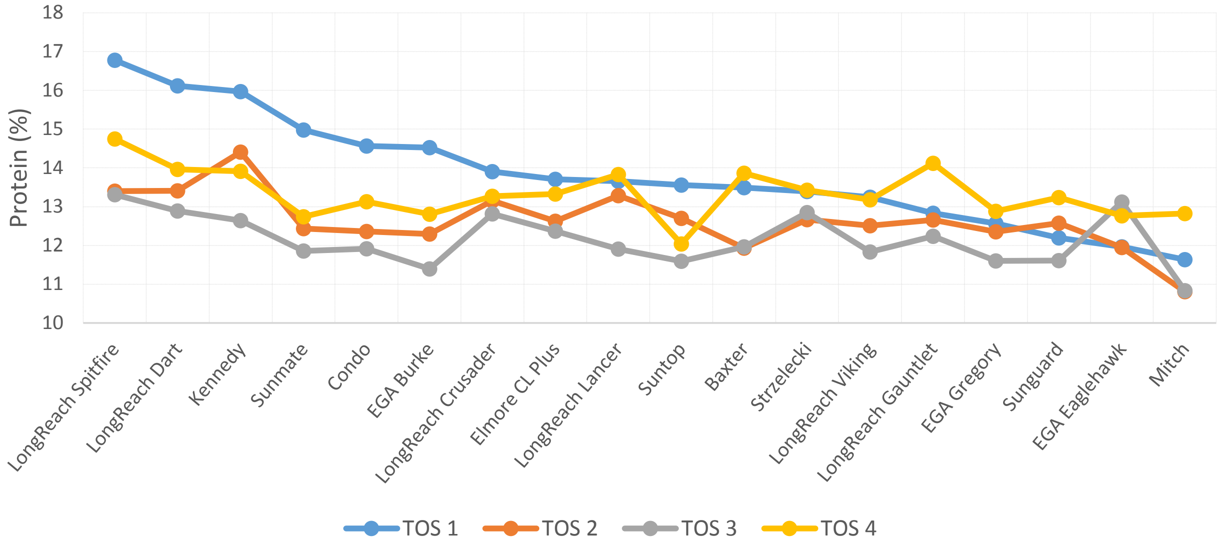

Figure 9. Grain protein (%) for all TOS dates and all varieties planted. LSD within a TOS was 0.62% and LSD between TOS events .66% (p=0.05)

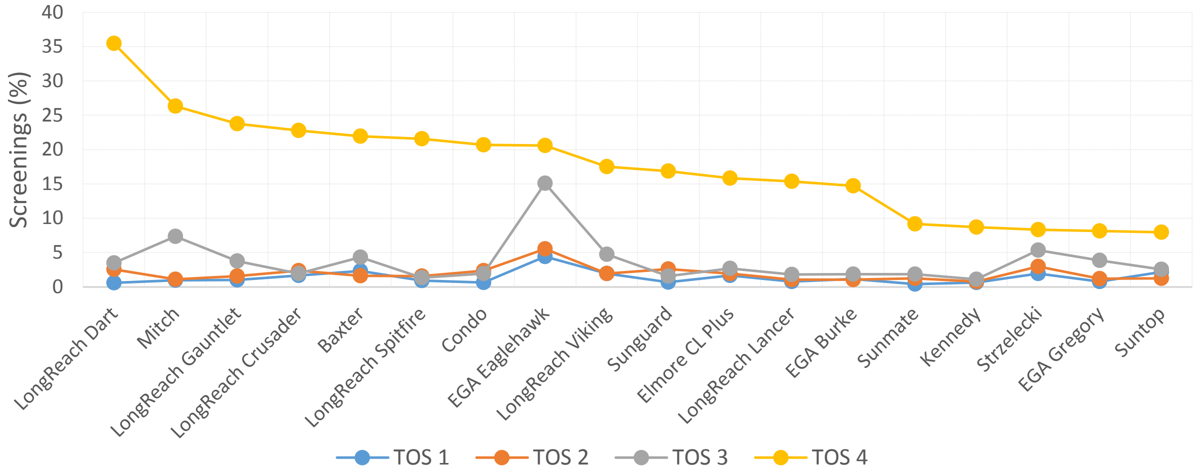

Figure 10. Grain screenings for all 18 varieties used in all four times of sowing. LSD of 0.16 % (P=0.05). Note the significant spike in screenings for TOS 4

country not prone to frost, medium to longer maturity varieties such as Mitch⌽, LongReach Lancer⌽ or EGA Gregory⌽ are recommended.

If frost risk is minimal and usually occuring in July or early August, there is potential to opt to flower before the coldest weather arrives. Quicker varieties such as Suntop⌽, Condo⌽, LongReach Spitfire⌽ and Elmore CL Plus⌽ have the ability to flower quickly and still yield in a mid-April plant. Planting in mid-April, varieties will not suffer from heat stress as much and consequently tend to tiller more, increasing yield potential.

By mid-May, the trials are showing that only a medium to quick variety should be considered unless a late July/early August frost is a significant concern. Seasonal conditions in 2016 suited the May plant, however it is rare to received so much rain in June and July in CQ, so that should be taken into consideration when reviewing these results.

Heat stress will have a significant impact on yield potential of a mid-June plant. If planting wheat, only opt for the quickest maturity varieties. An early to mid-August spring planting may be a more profitable use of a stored profile of water in this situation.

Time of sowing will have a significant effect on final yield result, with the mid-April plant consistently out yielding other planting dates. This planting window is not without significant frost risks, but significant yield bonuses are there for the taking by choosing the right variety of wheat with a maturity and disease package that suits your particular conditions.

Acknowledgements

The Variety Specific Agronomy Packages (VSAP) program is co-funded by the Grains Research and Development Corporation, New South Wales Department of Primary Industries and the Queensland Department of Agriculture and Fisheries.

Seed supplied by Australian Grain Technologies, Advanta Seeds, Heritage Seeds, Seednet and local growers, Scott and Gordon Muller.

Trial details

Location:	Field 5, Block 20 at QATC, Emerald
Crop:	Wheat
Soil type:	Grey Cracking Vertosol with a water holding capacity in excess of 230 mm
In-crop rainfall:	Starting plant available water was measured down to 90 cm at the time of planting (Table 1). 50 mm of irrigation was applied on 4 April, 28 April and 28 May to ensure suitable planting water for each TOS. There was no further irrigation after that time however we did receive 272 mm of rain on station between 16 March and 27 October 2016 (Figure 11)
Fertiliser:	Starting N on the site was 133 kg/ha, an additional 50 kg/ha of urea was applied at planting between the four planting rows of the machine. 30 kg/ha of Granulock Z® was also applied with the seed at planting

TOS 2 heads emerging while TOS 1 is approaching harvest in the background

EGA Eaglehawk$^{\circledP}$ was significantly slower than the other varieties, even for the late planting

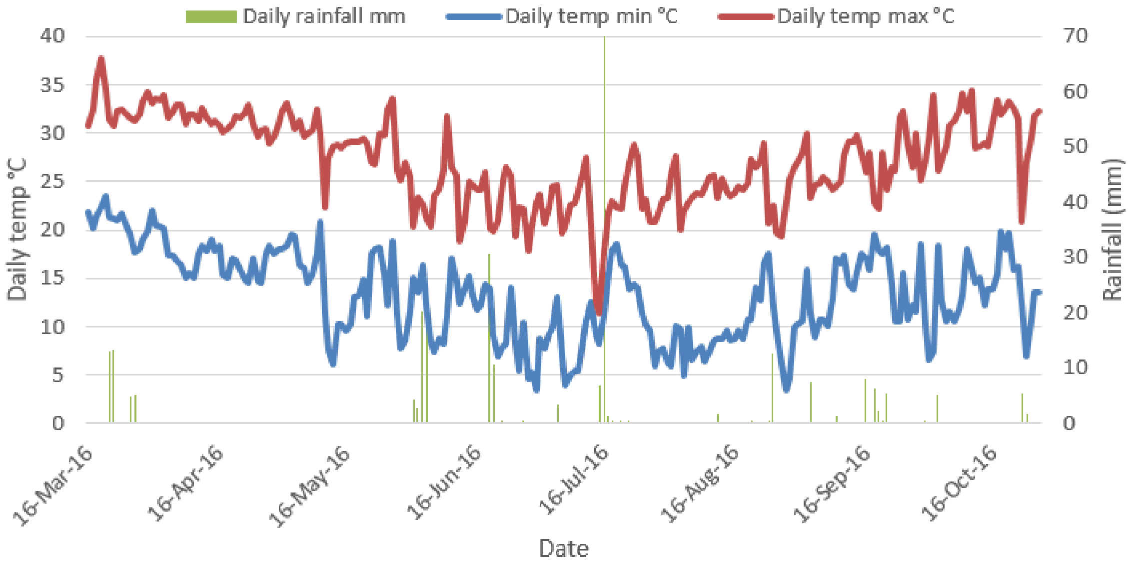

Figure 11. Weather data for the trial site

Appendix

Table A1. Days to flowering (50% anthesis)

Variety	TOS 1		TOS 2		TOS 3		TOS 4	
Condoⓓ	61	hi	55	i	74	ef	79	i
LongReach Dartⓓ	66	efg	55	i	72	f	79	i
Sunmateⓓ	56	j	55	i	72	f	81	hi
Suntopⓓ	51	k	55	i	72	f	85	fg
LongReach Crusaderⓓ	62	h	57	hi	76	e	84	gh
LongReach Spitfireⓓ	68	def	57	hi	76	e	79	i
Elmore CL Plusⓓ	63	gh	60	gh	76	e	85	gh
LongReach Vikingⓓ	58	ij	62	fg	84	d	91	de
EGA Burkeⓓ	62	h	63	fg	82	d	89	de
Kennedyⓓ	68	de	63	fg	76	e	85	efgh
Mitchⓓ	62	h	63	fg	84	d	90	de
Baxterⓓ	64	fgh	65	ef	81	d	88	ef
LongReach Gauntletⓓ	61	hi	67	e	84	d	89	de
Sunguardⓓ	63	fgh	67	e	84	d	88	ef
LongReach Lancerⓓ	74	c	78	d	89	c	94	c
EGA Gregoryⓓ	70	d	85	c	90	c	92	cd
Strzeleckiⓓ	91	b	99	b	104	b	98	b
EGA Eaglehawkⓓ	131	a	130	a	116	a	107	a
LSD for same TOS LSD for different TOS	3.57 3.60							

Table A2. Average yield (kg/ha)

Variety	TOS 1		TOS 2		TOS 3		TOS 4	
Condoⓓ	2729	ef	5032	ghi	5953	a	2514	abcd
LongReach Dartⓓ	1670	h	4311	j	4796	de	2097	efg
Sunmateⓓ	1464	h	4596	j	5702	ab	2739	abc
Suntopⓓ	2978	e	5375	defg	5901	a	2747	abc
LongReach Crusaderⓓ	3007	e	5084	fgh	5218	c	2389	cdef
LongReach Spitfireⓓ	1628	h	4660	ij	5348	bc	2483	abcde
Elmore CL Plusⓓ	2761	ef	5066	gh	5636	ab	2695	abc
LongReach Vikingⓓ	2558	fg	5202	efg	5632	ab	2034	fgh
EGA Burkeⓓ	2318	g	5562	bcde	5674	ab	2671	abc
Kennedyⓓ	2535	fg	5865	bc	5915	a	2822	a
Mitchⓓ	4726	ab	6955	a	4981	cde	1791	gh
Baxterⓓ	3729	cd	5493	cdef	4741	de	1873	gh
LongReach Gauntletⓓ	3582	d	5556	bcde	4697	e	1651	h
Sunguardⓓ	4095	c	5265	efg	5126	cd	2277	def
LongReach Lancerⓓ	3723	cd	5885	b	5321	bc	2407	bcdef
EGA Gregoryⓓ	3787	cd	5731	bcd	4959	cde	2793	ab
Strzeleckiⓓ	4992	a	5475	def	4264	f	1826	gh
EGA Eaglehawkⓓ	4592	b	4729	hij	3342	g	1044	i
LSD for same TOS LSD for different TOS	394 411							

Wheat: the effects of different planting dates on yield and plant physiology across different varieties—Goondiwindi

Andrew Erbacher
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?*

Key findings

1. Wheat should be planted early in the recommended planting window to maximise yield.
2. Heat stress has had a greater yield penalty than frost in this trial.
3. Using a combination of varieties, with varying maturity, and multiple planting dates will spread the risk of frost and heat stress.

Background

This trial is a repeat of the work done in 2015, reported in *Wheat varieties and the effects of different planting dates-Goondiwindi*[1]. All of the varieties grown in Queensland are spring type wheats, with minimal vernalisation requirements for anthesis to occur. In the 2015 trial the date of anthesis of a given variety was determined by the date of which it was planted. This trial also showed that days to anthesis and grain yield reduced for later planted crops, which suffered heat stress during anthesis and early grain-fill. As a frost free season maximum yields were achieved by planting early. The absence of frost in this trial and heat stress suffered by the slowest maturing varieties in the first planting date led to the decision to include an extra early planting date in the 2016 trial, with the 2nd, 3rd and 4th planting dates is 2016 similar to the three dates used in the 2015 trial.

CliMate suggests that at Goondiwindi, flowering should occur after 21 July for a 1 in 10 year frost risk, but before 19 September for a 1 in 10 year heat stress risk. The ideal flowering date where heat stress and frost risk are lowest is 30 August.

What was done

The site was under a centre pivot on an alluvial soil on the Weir River, allowing the opportunity for supplementary irrigation to ensure planting opportunities on the required date, which was necessary for the first two planting dates. Predicta B tests revealed no pathogens that would impact wheat yield. The trial was planted with double discs on 25 cm row spacing and a target population of 1 million plants per hectare.

Eighteen varieties were planted on four different times of sowing (TOS) at four week intervals:

- 4 April (TOS 1)
- 26 April (TOS 2)
- 24 May (TOS 3)
- 4 July (TOS 4)

The varieties grown in order of increasing maturity from slow to quick were (2017 Queensland wheat varieties guide): EGA Eaglehawk$^{\phi}$, Strzelecki$^{\phi}$, LongReach Lancer$^{\phi}$, EGA Gregory$^{\phi}$, LongReach Gauntlet$^{\phi}$, EGA Burke$^{\phi}$, EGA Wylie$^{\phi}$, Baxter$^{\phi}$, Sunguard$^{\phi}$, Mitch$^{\phi}$, Elmore CL Plus$^{\phi}$, Viking$^{\phi}$, Kennedy$^{\phi}$, Suntop$^{\phi}$, LongReach Spitfire$^{\phi}$, LongReach Crusader$^{\phi}$, Sunmate$^{\phi}$ and LongReach Dart$^{\phi}$.

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[1] Regional Research Agronomy Network (2015). Queensland Grains Research 2015, Department of Agriculture and Fisheries, Queensland.

Results

2016 had a warm, dry autumn, followed by a cool wet winter and spring. A total of 16 frosts (below 0°C at head height) were measured after head emergence of the earliest variety.

The greatest influence on grain yield and quality in this trial is the date at which anthesis occurred (Figure 1). Planting quick maturing varieties early in this season has subjected them to reduced yields due to frost. This yield reduction was 40 kg for each day that anthesis occurred before the last frost (21 August). From 23 September average daily temperatures consistently exceeded 30°C, and consequently there was a yield penalty of 100 kg for every day after this date that anthesis occurred. The late anthesis date also resulted in increased screenings, as a result of heat stress. This trend from late flowering is consistent with what was observed in the 2015 trial, however in that season the effects of heat stress were noticeable from 10 September. Temperature stress had no effect on yield for varieties flowering in September and varieties also achieved their longest days to anthesis during this period (TOS 3, Table 1).

A hot and dry April required TOS 1 to be dry sown and irrigated up. Sixteen of 18 varieties developed very quickly from TOS 1 with days to 50% anthesis 35 days quicker than the May planted crop (Table 1). This increased the effect of planting date on anthesis date, and as a result TOS 1 flowered in June and was subjected to seven frosts during this critical period.

Kangaroos ate the developing heads of this early crop, so yield was not able to be measured for those 16 varieties. Strzelecki$^{\Phi}$ and EGA Eaglehawk$^{\Phi}$ appeared to have been less influenced by the early heat, having their longest days to anthesis from the early planting date, and therefore flowering at a more appropriate time of 2 August and 1 September respectively.

The late April planted wheat (TOS 2) was again planted in warm conditions, so was seven days earlier to anthesis than the 2015 trial. The bigger impact between the two seasons was the fact that frosts occurred 30 days later in 2016 than the 2015 season.

TOS 4 varieties had shorter period to anthesis than TOS 2 and TOS 3. This reduction in days to anthesis has allowed some of the quick maturing varieties to flower late inside the ideal window, producing similar yields as their earlier TOS, but with increased screenings due to the heat stress.

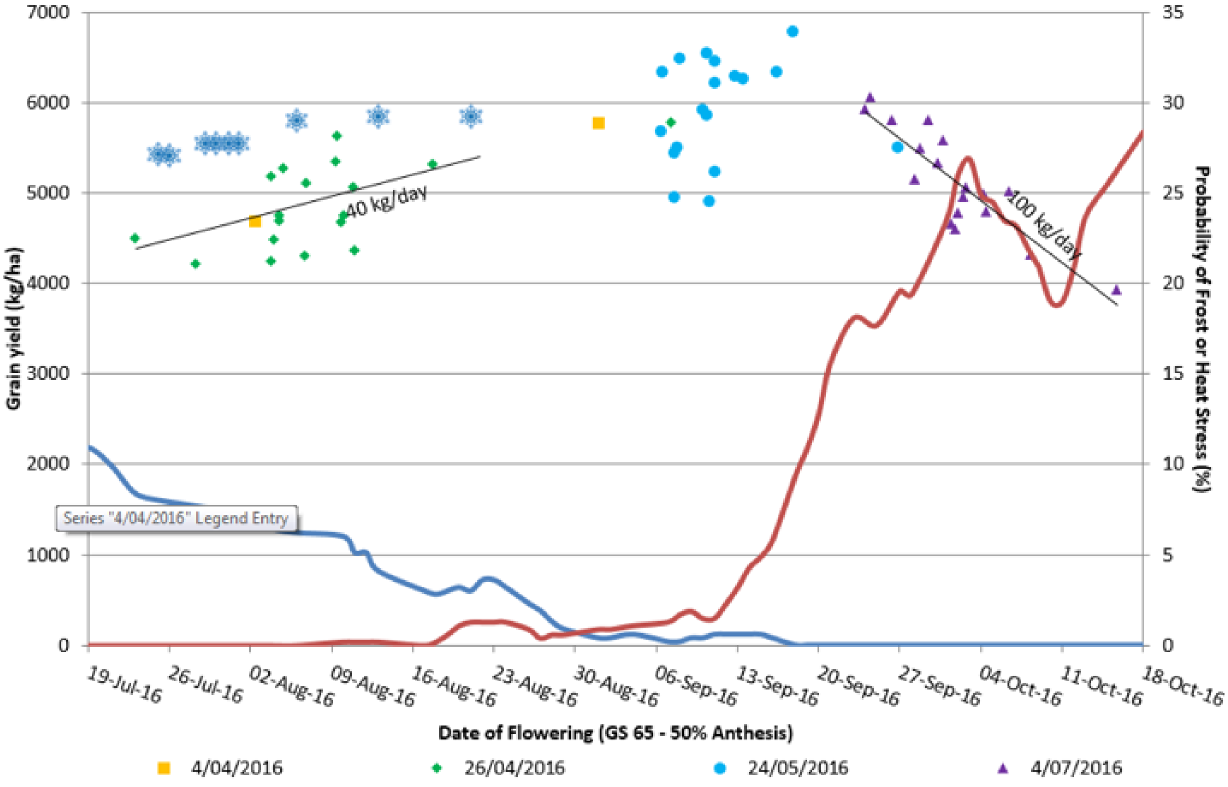

Figure 1. Grain yields of wheat for the date at which 50% anthesis occurred. The lines indicate the probability of Goondiwindi screen temperatures <0°C and >30°C (www.australianclimate.net.au/). ❄Indicates the dates that the minimum temperature was <0°C at head height in this trial

Table 1. Days required for wheat varieties to reach 50% anthesis for the four planting dates

Variety	TOS 1 1 April	TOS 2 26 April	TOS 3 24 May	TOS 4 4 July
Average	**82 d**	**103 b**	**110 a**	**90 c**
LongReach Dart$^{\phi}$	59 d	88 b	105 a	82 c
Sunmate$^{\phi}$	64 d	87 b	107 a	83 c
Suntop$^{\phi}$	68 d	99 b	109 a	88 c
Elmore CL Plus$^{\phi}$	69 d	100 b	109 a	89 c
LongReach Spitfire$^{\phi}$	71 d	99 b	107 a	87 c
LongReach Crusader$^{\phi}$	71 d	101 b	107 a	84 c
Kennedy$^{\phi}$	73 d	95 b	106 a	88 c
Viking$^{\phi}$	74 d	106 b	109 a	91 c
EGA Burke$^{\phi}$	74 d	99 b	107 a	90 c
LongReach Gauntlet$^{\phi}$	76 d	105 b	113 a	92 c
Baxter$^{\phi}$	77 d	99 b	110 a	86 c
Sunguard$^{\phi}$	81 d	102 b	110 a	91 c
LongReach Lancer$^{\phi}$	81 d	104 b	117 a	95 c
Mitch$^{\phi}$	82 c	106 a	110 a	91 b
EGA Wylie$^{\phi}$	87 c	105 b	110 a	90 c
EGA Gregory$^{\phi}$	103 b	104 b	112 a	93 c
Strzelecki$^{\phi}$	121 a	115 b	115 b	96 c
EGA Eaglehawk$^{\phi}$	150 a	133 b	126 c	104 d
LSD for different TOS:	*4.53*			
LSD for same TOS:	*4.42*			

Letters indicate significantly different days to anthesis for varying planting dates within a variety.

Implications for growers

This trial demonstrated a yield benefit for matching the planting date with the length to maturity of a variety to maximise yield potential. With the presence of multiple frosts in this season there was a greater benefit to delaying flowering than observed in the 2015 trial, however the yield penalty for delaying flowering later than ideal has had a much greater impact.

Both this trial and the 2015 trial have achieved the best yields by flowering around 30 August, which is the date CliMate indicates both heat stress and frost risk are lowest. However variation in the window around this date between the two seasons reinforces the benefit of using a combination of varieties with varying maturity and multiple planting dates to spread the risk of frost and heat stress.

All varieties will mature faster if planted late in the season, but once planting dates are delayed such that flowering within the ideal window is not possible, maximum yields would be achieved by planting the quickest maturing varieties available.

Acknowledgements

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

The Variety Specific Agronomy Packages (VSAP) program is co-funded by the Grains Research and Development Corporation, New South Wales Department of Primary Industries and the Queensland Department of Agriculture and Fisheries.

Seed supplied by Australian Grain Technologies, Advanta Seeds, Heritage Seeds and Seednet.

Trial details

Location:	Goondiwindi
Soil type:	Black Vertosol
Crop:	Wheat
Previous crop:	Chickpea
PAW:	60, 65, 80 and 140 mm
In-crop rainfall:	330, 315, 300 and 225 mm
Fertiliser:	30 kg/ha Granulock Z®
Nitrogen:	320 kg N/ha

Establishing wheat, with more advanced TOS in the background

Varieties in various stages of head development in TOS 4

Wheat: the effects of different planting dates on yield and plant physiology across different varieties—Warwick

Andrew Erbacher
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?*

Key findings

1. Time to anthesis was reduced for later time of sowing.
2. Average grain yield was not affected by time of sowing.
3. Selecting varieties to match planting date and agronomic traits will improve yield potential.

Background

The Hermitage Research Station site, located 8 km east of Warwick on the Southern Darling Downs, is typified by reliable rainfall and long cold winters with up to 20 frosts per year, whereas late season heat stress is less severe.

The trial paddock was long fallowed from sorghum in 2014/15 and had 150 mm of plant available water (PAW) after watering up the first time of sowing (TOS). Predicta B tests did not reveal any pathogens that would impact wheat yield.

What was done

Twenty varieties were planted on three different TOSs at four week intervals. The timing was based on a traditional mid–June planting, with an earlier and later planting opportunity. Planting dates were:

- 17 May (TOS 1)
- 14 June (TOS 2)
- 22 July (TOS 3)

The varieties in order of increasing maturity from slow to quick (2017 Queensland wheat varieties guide) were: EGA Eaglehawk$^{\phi}$, Suntime$^{\phi}$, LongReach Lancer$^{\phi}$, EGA Gregory$^{\phi}$, LongReach Flanker$^{\phi}$, LongReach Gauntlet$^{\phi}$, EGA Burke$^{\phi}$, EGA Wylie$^{\phi}$, Baxter$^{\phi}$, Sunguard$^{\phi}$, Mitch$^{\phi}$, Elmore CL Plus$^{\phi}$, Viking$^{\phi}$, Kennedy$^{\phi}$, Suntop$^{\phi}$, LongReach Spitfire$^{\phi}$, LongReach Crusader$^{\phi}$, Sunmate$^{\phi}$, Condo$^{\phi}$ and LongReach Dart$^{\phi}$.

Results

The average of all varieties showed no difference in days to anthesis (GS65) between TOS1 and TOS2 (Table 1). Only nine of the 20 varieties tested had reduced days to anthesis in this period, of which included the six slowest varieties. In contrast all varieties were approximately three weeks quicker to anthesis for TOS3 than TOS2.

The average grain yield of all varieties was not significantly different between the three times of sowing. This average response was evident in 14 of the 20 varieties tested, with six varieties measuring a significant difference between any of the planting dates.

The majority of the varieties with no significant yield difference for different planting dates were the quick and main season varieties. LongReach Dart$^{\phi}$ was the only variety to have a significant yield increase from TOS1 to 2. This would be attributed to a cold period with two consecutive frost days on 18 August, coinciding with head emergence.

At the traditional main season planting date (TOS2) there was little variation in yields between the varieties (Table 1). For the early planting date (TOS1) the slow maturing varieties (Mitch$^{\phi}$, EGA Gregory$^{\phi}$, LongReach Lancer$^{\phi}$, EGA Eaglehawk$^{\phi}$ and Suntime$^{\phi}$) were able to take advantage of the longer growing season and increase their yield, whereas there was no advantage for planting the faster maturing varieties early.

Table 1. Days to 50% anthesis (GS65) and grain yields for varieties planted on three different dates (varieties are in order of anthesis from TOS1)

	Days to 50% anthesis			Grain yields (kg/ha)					
Variety	TOS1	TOS2	TOS3	TOS1		TOS2		TOS3	
Average	**116a**	**113a**	**91b**	6329	ns	6000	ns	5704	ns
LongReach Dartᶲ	107	104	83	4975	j	6781	ab	6140	abcd
Condoᶲ	107	105	84	5778	fghi	5897	cdef	6370	ab
Sunmateᶲ	109	110	88	6772	bcd	6131	bcde	6419	ab
Kennedyᶲ	110	110	88	6375	cdef	5657	defg	5426	efgh
LongReach Spitfireᶲ	110	106	85	6095	defghi	6716	ab	5511	defgh
LongReach Crusaderᶲ	110	106	86	5790	fghi	5960	cdef	5737	bcdef
Elmore CL Plusᶲ	112	114	90	6394	cdef	6367	abcd	6361	abc
Baxterᶲ	112	109	89	5368	ij	5309	fg	4858	h
LongReach Gauntletᶲ	113	115	92	6366	cdefgh	5612	efg	5680	cdefg
EGA Burkeᶲ	115	111	91	5622	hij	5167	g	5259	fgh
Suntop ᶲ	116	114	89	6729	bcde	6378	abc	6048	abcde
EGA Wylieᶲ	116	113	91	5638	ghij	5315	fg	5096	fgh
Vikingᶲ	117	116	91	6713	bcde	5922	cdef	5985	abcde
LongReach Flankerᶲ	118	116	92	6332	defg	5827	cdefg	5536	defg
Sunguard ᶲ	118	112	93	6646	bcde	5816	cdefg	5459	defgh
Mitchᶲ	121	113	93	7027	bc	5713	cdefg	5455	defgh
EGA Gregoryᶲ	121	115	93	6067	efghi	5907	cdef	5677	cdefg
LongReach Lancerᶲ	122	118	97	7124	b	6670	ab	6492	a
Suntimeᶲ	124	117	96	7957	a	7079	a	5535	defgh
EGA Eaglehawkᶲ	138	128	102	6814	bcd	5770	cdefg	5034	gh
LSD for same TOS	*2.5*			*693*					
LSD for different TOS	*3.2*			*870*					

Values with common letters are not significantly different within a TOS. Differences need to be greater than the LSD to be significant (p=0.05)

Only one variety (Suntimeᶲ) measured a significant yield reduction by delaying sowing from TOS2 to TOS3. However, for this late planting date (TOS3) the quicker maturing varieties tended to achieve the highest yields (Table 1).

Soil water was measured for EGA Gregoryᶲ at planting and harvest of each of the three TOS. When combined with in-crop rainfall it showed the water use efficiency (WUE) increased for TOS3, with 12 kg/mm for TOS1 and 2, and 13.5 kg/mm for TOS3. This difference in WUE is the result of a 70 mm storm shortly after TOS2 was planted, which was largely un-utilised due to runoff.

Implications for growers

Four of the five varieties that measured significant yield reductions for later planting date were all slower maturing varieties that had reduced days to anthesis for each of the three TOS. This could be attributed to the warming temperatures later in the season accelerating development and therefore reducing yield. While only one variety suffered yield reduction as a result of frost in this trial, the Australian CliMate model shows there is a high likelihood of frost for early flowering crops in this area.

While the average of all varieties tested suggest there is no yield difference for planting date in this climate, varieties do need to be selected for their most appropriate planting window in order to maximise yield potential. Reference guides such as the Queensland Wheat Varieties Guide are a good source of information for deciding the best planting window for individual varieties.

Acknowledgements

The Variety Specific Agronomy Packages (VSAP) program is co-funded by the Grains Research and Development Corporation, New South Wales Department of Primary Industries and the Department of Agriculture and Fisheries.

Seed supplied by Australian Grain Technologies, Advanta Seeds, Heritage Seeds and Seednet.

Trial details

Location:	Hermitage Research Station, Warwick
Crop:	Wheat
Soil type:	Vertosol
In-crop rainfall:	507 mm, 482 mm and 418 mm
PAW:	64 mm, 75 mm and 113 mm
Fertiliser:	35 kg/ha Granulock Z®

TOS 1 flowering with later TOS in the background

Variation in flowering dates of TOS 1

Wheat: impact of population and row spacing effect on the phenology and yield potential—Emerald

Darren Aisthorpe and Ellie McCosker
Department of Agriculture and Fisheries

Research Questions: *Can changing target population or row spacing have a significant effect on the phenology and yield potential of wheat? If so, are there any clear varietal differences that can be used to optimise yield potential?*

Key findings

1. Maximise population to maximise yield and grain qualities.
2. It is harder to establish higher populations on wider rows.
3. 50 cm row spacing may not be as detrimental to yield potential as previously thought.

Background

Previous research on optimum plant populations in Queensland and New South Wales has consistently indicated an established population of 1 million plants per hectare is optimum for maximising yield. In addition, research conducted in Central Queensland (CQ) from 2002–2004 by Spackman, Reid, et al.[1] concluded that "When yield exceeds 2.5 t/ha, yield loss of 0.3–0.5 t/ha is likely with rows wider than 25 cm and the yield loss is likely to be higher in 50 cm than 37.5 cm rows."

In 2015, the initial Variety Specific Agronomy Packages (VSAP) trial in CQ explored the relationships between different wheat varieties, time of sowing and plant population on yield. It was planted on 50 cm row spacing, in line with current grower practice within the region. Results showed that the average yield across varieties for the mid-April time of sowing (TOS) plant was 4.1 t/ha and for the mid-May plant 3.3 t/ha. The trials also indicated that there was no strong relationship between population and yield once plant populations exceeded 600,000 plants per ha.

These observations did not support previously reported research outcomes and raised two questions which required further exploration.

1. Why didn't yields increase in line with populations?
2. What was the impact of the wide rows on yield given previous research shows that yield losses occurred on wide rows when yields exceeded the benchmark of 2.5 t/ha.

What was done?

The trial was planted at the Queensland Agricultural Training College (QATC) – Emerald on 12 May 2016 using a cone planter equipped with Boss TX 45 parallelograms and double disc shanks that can plant on both 25 cm and 50 cm row spacing. Starting plant available water was 147 mm down to 90 cm.

The varieties (Table 1) were standardised across all southern Queensland sister sites. LongReach Gauntlet$^{\phi}$ replaced Kennedy$^{\phi}$ from the 2015 variety list. Target populations were 300 000, 600 000, 900 000 and 1.5 million.

Table 1. Planting seed qualities pre-plant 2016

Variety	LongReach Dart$^{\phi}$	EGA Gregory$^{\phi}$	LongReach Gauntlet$^{\phi}$	LongReach Lancer$^{\phi}$	LongReach Spitfire$^{\phi}$	Suntop$^{\phi}$	Average
1000 seed weight (g)	36	42	25	46	40	43	39
Seeds/kg	27778	23981	40650	21739	25000	23256	27067
Seed Germ	79%	97%	75%	86%	88%	91%	86%

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[1] Central Queensland Sustainable Farming Systems 'Project Update' Newsletter, March 2005, page 8

Establishment counts were conducted on 23 May 2016, counting 1 m x 4 rows per plot for both spacing configurations. In-crop measurements included head emergence, 50% anther appearance and head height assessment. Harvest took place on 10 October 2016 and all grain was weighed and tested for moisture, protein, screenings, test weights and seed size.

Results

Establishment

Significant differences were measured in plant establishment for most of the population x row spacing configurations, with, only the 50 cm 900,000 target population and the 25 cm 600,000 target population treatments not significantly different from each other (Table 2). The average difference in established plants between the wide row configurations and narrow row configurations was 75%.

Table 2. Spacing x population comparison

Spacing (cm)	Target population (plants/ha)	Mean establishment (plants/ha)		% of 25 cm germination
25	1,500,000	1,367,900	a	
50	1,500,000	1,081,500	b	79%
25	900,000	937,500	c	
50	900,000	703,100	d	75%
25	600,000	655,000	d	
50	600,000	472,300	e	72%
25	300,000	305,000	f	
50	300,000	230,400	g	76%

Letters different to each other denote a statistically difference in the values (P<0.05)

A significant difference in establishment between varieties (Table 3) did not correlate with the germination tests pre-plant (Table 1). LongReach Dart⌽ and LongReach Spitfire⌽ had the best average germination across all treatments, while Suntop⌽ had the lowest (Table 3).

Table 3. Average plants established x variety across all population and row spacing treatments

Variety	Mean establishment (plants/ha)	
LongReach Dart⌽	780,000	a
LongReach Spitfire⌽	750,000	a
LongReach Lancer⌽	740,000	ab
LongReach Gauntlet⌽	700,000	bc
EGA Gregory⌽	680,000	cd
Suntop⌽	650,000	d

Treatments with different letters indicate a significant difference in established populations (P<0.05)

Flowering

Significant differences in average days to flower were measured (Table 4). The quickest varieties were LongReach Dart⌽ and Suntop⌽ followed by LongReach Spitfire⌽ and EGA Gregory⌽.

Table 4. Average days to flowering for varieties non-responsive to population (p=0.05)

Variety	Mean days to flower	
EGA Gregory⌽	91.78	a
LongReach Spitfire⌽	81.19	b
Suntop⌽	78.56	c
LongReach Dart⌽	78.25	c

Plant population significantly impacted on days to flower of two varieties (LongReach Lancer⌽ and LongReach Gauntlet⌽). The mean days to flower of LongReach Lancer⌽ was reduced by nine days from the low population to the high population while LongReach Gauntlet⌽ was reduced by four days. No other varieties showed any significant trends.

Table 5. Days to flowering response to varieties which were responsive to population (p=0.05)

Variety	Plant population	Mean days to flower	(within variety)
LongReach Gauntlet⌽	30	89.52	a
	60	88.14	ab
	90	86.75	b
	150	83.97	c
LongReach Lancer⌽	30	95.02	a
	60	93.04	b
	90	91.06	c
	150	87.11	d

Effect on yield

Population had a significant and consistent effect on yield, however yield increase did change significantly between varieties. The greater the increase in yield (Table 6) for every additional 100,000 plants/ha established, the more responsive that particular variety was to population. Longer season varieties EGA Gregory⌽ and LongReach Lancer⌽ were the least responsive, while Suntop⌽ and LongReach Gauntlet⌽ were the most responsive.

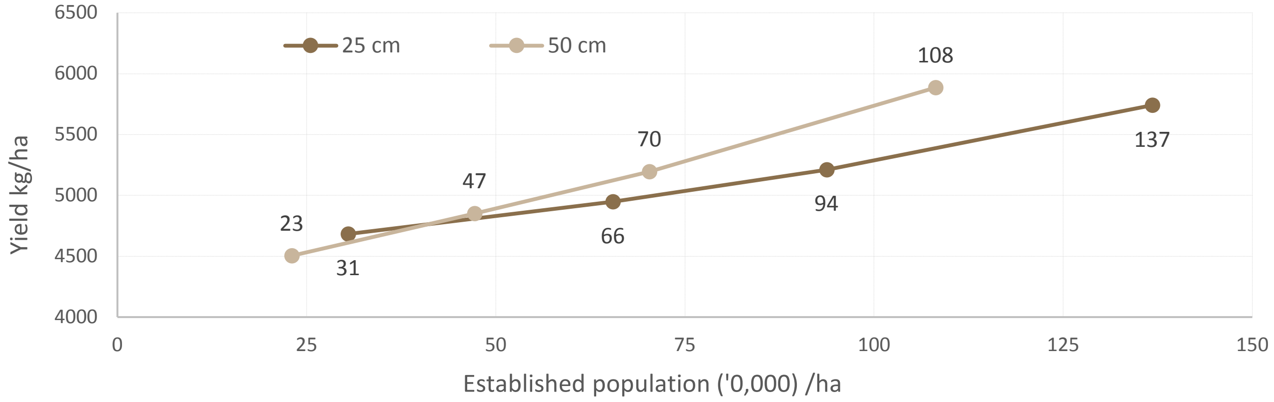

Figure 1. The effect on average yield when population and row spacing were manipulated

Table 6. Yield response as population increases across varieties and row spacing

Variety	Increase in yield (t/ha) for every additional 100,000 plants/ha	
Spacing	*25 cm*	*50 cm*
LongReach Gauntlet$^{\phi}$	0.12	0.15
Suntop$^{\phi}$	0.11	0.14
LongReach Dart$^{\phi}$	0.09	0.12
LongReach Spitfire$^{\phi}$	0.08	0.11
LongReach Lancer$^{\phi}$	0.08	0.10
EGA Gregory$^{\phi}$	0.04	0.07
Average	**0.09**	**0.12**

The average yield of all varieties was highest in the wider row spacing treatments outperforming the narrower row spacing configuration at populations greater than 500,000 plants per hectare, despite having significantly less plants emerged for the same yield (Figure 1).

Suntop$^{\phi}$ was the highest yielding variety for the trial achieving the highest average yield for all populations and both spacing configuration. LongReach Spitfire$^{\phi}$ and LongReach Lancer$^{\phi}$ yielded significantly less than Suntop$^{\phi}$ for both row spacing and population, but were not significantly different from each other. EGA Gregory$^{\phi}$, although not significantly different from Suntop$^{\phi}$ at low populations for the different row spacings did not perform at the higher plant populations and yielded significantly less at the higher plant populations for both row spacings.

LongReach Dart$^{\phi}$ and LongReach Gauntlet$^{\phi}$ yielded significantly less than other varieties at low population for both row spacings. Although LongReach Dart$^{\phi}$ also yielded significantly less than all other varieties at high plant populations for both row spacings, LongReach Gauntlet$^{\phi}$ performed significantly better, particularly when planted in 25 cm row spacings at high populations.

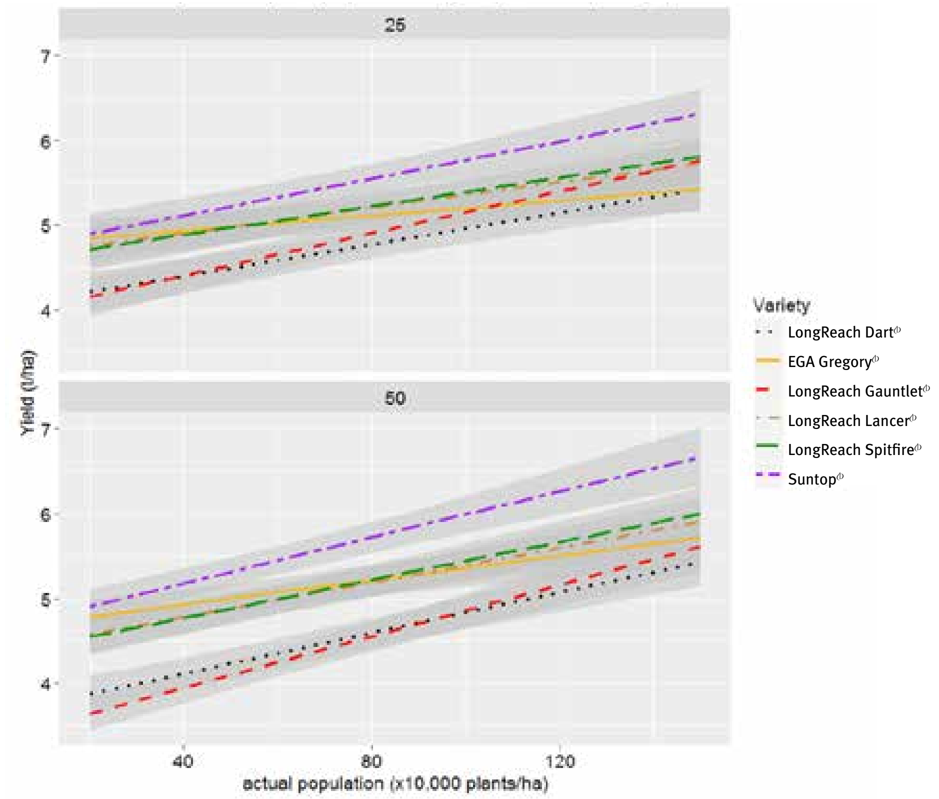

Figure 2. Varietal effect of row spacing and population on yield

Grain qualities

Screenings decreased as population increased (Figure 3) for both row spacings. At low populations the wide row treatments had higher screenings than the narrow row populations however this trend reduced as populations increased. Varieties such as LongReach Dart$^{\phi}$, EGA Gregory$^{\phi}$ and LongReach Gauntlet$^{\phi}$ all had significantly higher screenings than LongReach Spitfire$^{\phi}$ and Suntop$^{\phi}$ at the low population levels.

Table 7. Variety x target population effect on protein

Variety	Target population	Mean protein (%)	
LongReach Lancer$^{\phi}$	30	14.12	a
LongReach Lancer$^{\phi}$	150	14.31	ab
LongReach Spitfire$^{\phi}$	150	14.06	abc
LongReach Spitfire$^{\phi}$	90	14.01	abc
LongReach Spitfire$^{\phi}$	60	13.99	abc
LongReach Spitfire$^{\phi}$	30	13.97	abc
LongReach Lancer$^{\phi}$	60	13.88	bc
LongReach Dart$^{\phi}$	150	13.76	cd
LongReach Lancer$^{\phi}$	90	13.83	cd
LongReach Dart$^{\phi}$	90	13.67	d
LongReach Dart$^{\phi}$	60	13.48	e
LongReach Gauntlet$^{\phi}$	30	13.37	ef
EGA Gregory$^{\phi}$	30	13.33	efg
EGA Gregory$^{\phi}$	60	13.31	efg
EGA Gregory$^{\phi}$	90	13.26	fg
LongReach Dart$^{\phi}$	30	13.20	fghi
EGA Gregory$^{\phi}$	150	13.04	fghi
LongReach Gauntlet$^{\phi}$	150	13.06	fghi
LongReach Gauntlet$^{\phi}$	60	13.16	gi
LongReach Gauntlet$^{\phi}$	90	13.05	hj
Suntop$^{\phi}$	150	12.66	ij
Suntop$^{\phi}$	30	12.06	k
Suntop$^{\phi}$	90	12.05	k
Suntop$^{\phi}$	60	11.98	k
Average LSD = 0.30			

Spacing	Mean	Standard error	
50	13.53	0.11	a
25	13.15	0.11	b

LSD = 0.37; Treatments with different letters are significantly different (p=0.05)

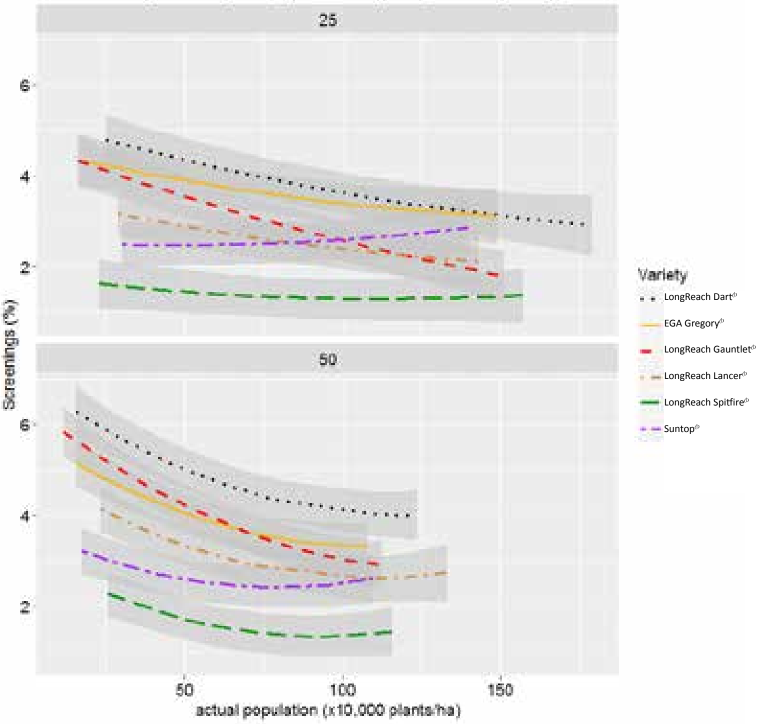

Figure 3. Effect of variety, population and row spacing on screenings

Significant differences in protein were identified between varieties. Both LongReach Lancer$^{\phi}$ and LongReach Spitfire$^{\phi}$ had consistently the highest protein levels when compared to other varieties while Suntop$^{\phi}$ consistently had the lowest protein levels. Population had no significant effect on protein, however there was a small significant difference between row spacing configurations (Table 7).

Implications for growers

Very good weather conditions through this trial have provided excellent growing conditions, directly influencing results. When considering planting options, growers should consider all available information and not base their decisions on one set of data.

The key messages for growers are:

1. Maximise population to maximise yield and grain qualities. Last year we saw yield effect virtually reduced to nil for most varieties once we hit a population in excess of 500,000-600,000 plants/ha. In 2016 we had a lot more in-crop rain, milder conditions for longer at the end of the season, and despite the dry finish, we saw a yield response right through the population range planted.

2. It is harder to establish higher populations on wider rows. Figure 1 shows the average plant establishment of all varieties in the wider row spacing configuration (50 cm) was significantly lower than it was in the narrower spacing (25 cm) for the same targeted plant populations. Growers should consider this difference when setting seeding rates to maximise yield.
3. 50 cm row spacing may not be as detrimental to yield potential as previously thought. HOWEVER… High established populations are a must, earlier plantings which will avoid heat stress at the end of the season are strongly advised and varietal selection may be important as there were some clear varietal differences in this trial.

Acknowledgements

The Variety Specific Agronomy Packages program is a continuation of co-funded research between New South Wales Department of Primary Industries and the Grains Research and Development Corporation. This work was contracted to the Department of Agriculture and Fisheries Regional Agronomy Network to complete six trials per year across the Queensland grain belt in 2015 and 2016.

Seed supplies from Australian Grain Technologies, Advanta Seeds, Heritage Seeds and Seednet for the supply of seed for the various VSAP trials.

We would also like to acknowledge and thank our co-operators who allow us to conduct these trials on their private properties.

Trial details

Location:	Field 5, Block 20 at the Queensland Agricultural Training College, Emerald,
Crop:	Wheat
Soil type:	Grey Cracking Vertosol with a water holding capacity in excess of 230 mm
Available water:	At planting, the trial had starting plant available water of 147 mm down to 90 cm. An additional 75 mm of water was applied on the 29 May. There was no further irrigation after that time. Rainfall can be viewed in Figure 4
Fertiliser:	Starting N on the site was 133 kg/ha, an additional 20 kg/ha of N was applied at planting across all seven planting rows of the machine through a bulk fertiliser box. 30 kg/ha of Granulock Z® was also applied with the seed at planting

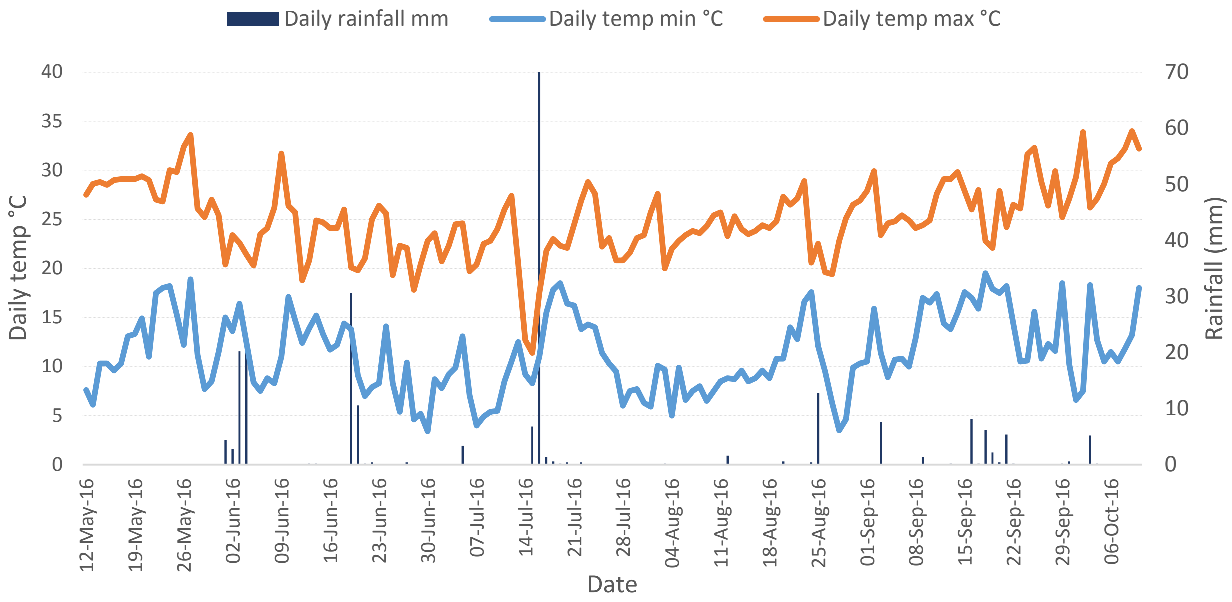

Figure 4. Weather data for Emerald site

Wheat: impact of population effect on phenology and yield—Goondiwindi

Andrew Erbacher
Department of Agriculture and Fisheries

Research Questions: *Can changing target population have a significant effect on the phenology and yield of wheat? Are there varietal differences which can be used to optimise yield potential?*

Key findings

1. Planting rates may need to be adjusted for each seed lot, to establish the desired plant population.
2. Increasing plant populations increased yield in one of the six varieties in this trial, but improved grain quality (screening) in all varieties.
3. Lower plant populations delayed anthesis by up to seven days.

Background

Previous research by a range of sources into optimum plant populations in Queensland and New South Wales has consistently indicated that a target rate of establishment of 1 million plants per hectare is optimum for maximising yield. However, is this number consistent across regions and seasonal conditions and various maturities or varieties?

This trial is a repeat of the 2015 Goondiwindi trial, reported in *Wheat varieties and the effects of different planting dates*, from the Queensland Grains Research—2015 publication. In 2015, we saw yield reductions for populations lower than 600,000 plants per hectare, however higher populations were not established in that trial. What needs to be determined is if overpopulating has any adverse impacts.

What was done?

Located 35 km north of Goondiwindi, the site was planted using a double disc planter on 25 cm row spacing. The paddock was long fallowed from 2014/15 sorghum, and had 220 kg N/ha and 85 mm of plant available water (PAW) at planting. Predicta B tests indicated there were no pathogens likely to cause a yield reduction in wheat.

Six varieties were planted on 1 June 2016 at four target populations. Planting rates were adjusted for seed size, germination percentage, and an estimated establishment rate of 85%. Planting rates varied between varieties, from 35 kg/ha to 57 kg/ha for the target population of 900,000 plants/ha (Table 1).

Target populations were:

1. 300,000 plants/ha
2. 600,000 plants/ha
3. 900,000 plants/ha
4. 1,500,000 plants/ha

The varieties in order of increasing maturity from slow to quick were (2017 Queensland wheat varieties guide):

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

Results

Achieved populations were close to the target, with slightly higher than expected populations across most treatments, however establishment was reduced for some of the higher density plots (Table 1).

Five of the six varieties tested had no difference in yield for changing populations in this trial. LongReach Gauntlet$^{\phi}$ did show a significant increase in grain yield for increasing populations. The trend for LongReach Gauntlet$^{\phi}$ was for an extra 60 kg grain/ha for every 100,000 plants/ha established. This equates to 720 kg/ha yield gain between 300,000 and 1,500,000 plants/ha (Figure 1).

Table 1. Planting rates and actual populations established

	Planting rate (kg/ha)				Established population ('000 /ha)			
Target population	*300,000*	*600,000*	*900,000*	*1,500,000*	*300,000*	*600,000*	*900,000*	*1,500,000*
Average	16	31	47	79	349	681	946	1,460
LongReach Dartᶲ	16	32	48	80	391	680	1,051	1,787
LongReach Gauntletᶲ	12	23	35	58	349	743	950	1,528
EGA Gregoryᶲ	15	30	46	76	320	658	884	1,240
LongReach Lancerᶲ	19	38	57	95	370	705	1,063	1,564
LongReach Spitfireᶲ	16	32	48	80	345	663	1,000	1,425
Suntopᶲ	17	33	50	83	320	638	728	1,215

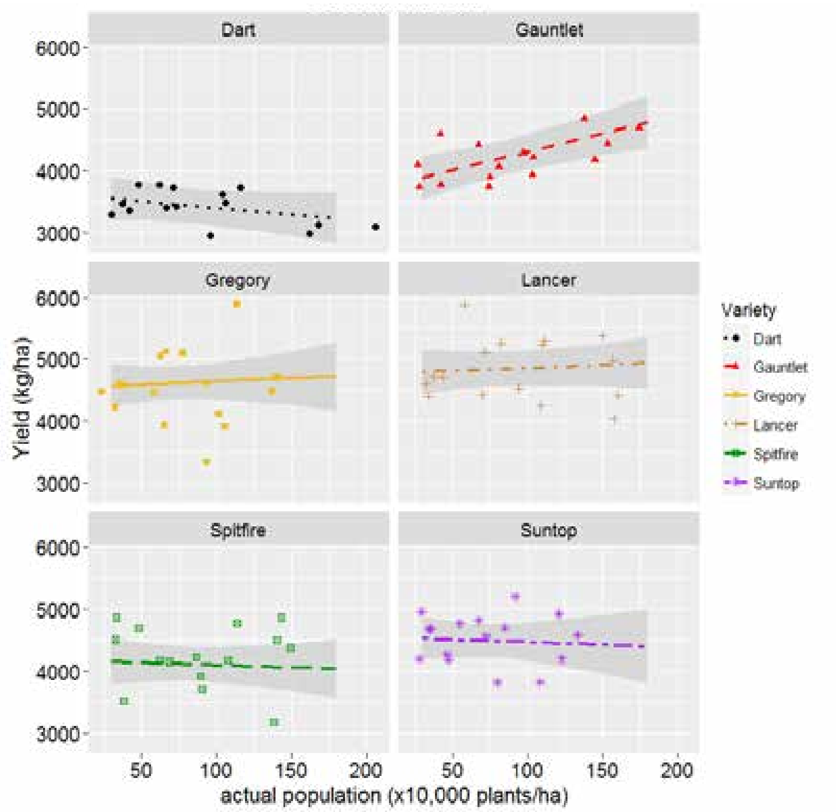

Figure 1. Grain yield for increasing plant populations. Five varieties had no significant difference in yield for changing populations. LongReach Gauntlet did have significant increase in yield for increasing populations (p=0.02)

Increasing population also had a significant effect on days to anthesis, with all six varieties slower to flower at lower populations. For EGA Gregoryᶲ, LongReach Spitfireᶲ and LongReach Dartᶲ there was three days difference in time to 50% anthesis between the lowest and highest populations, however for Suntopᶲ, LongReach Gauntletᶲ and LongReach Lancerᶲ the low populations were up to seven days slower to 50% anthesis than the highest population.

The time of sowing trial in the same district and the same season showed a decrease in yield, due to heat stress, of 100 kg /ha for each day that flowering was delayed after 25 September. A seven day delay in anthesis could have a large impact in yield on a later sown crop, however in this trial all plots reached 50% anthesis prior to 15 September, so heat stress was unlikely to have had an impact.

Wheat varieties and population trial ready for harvest

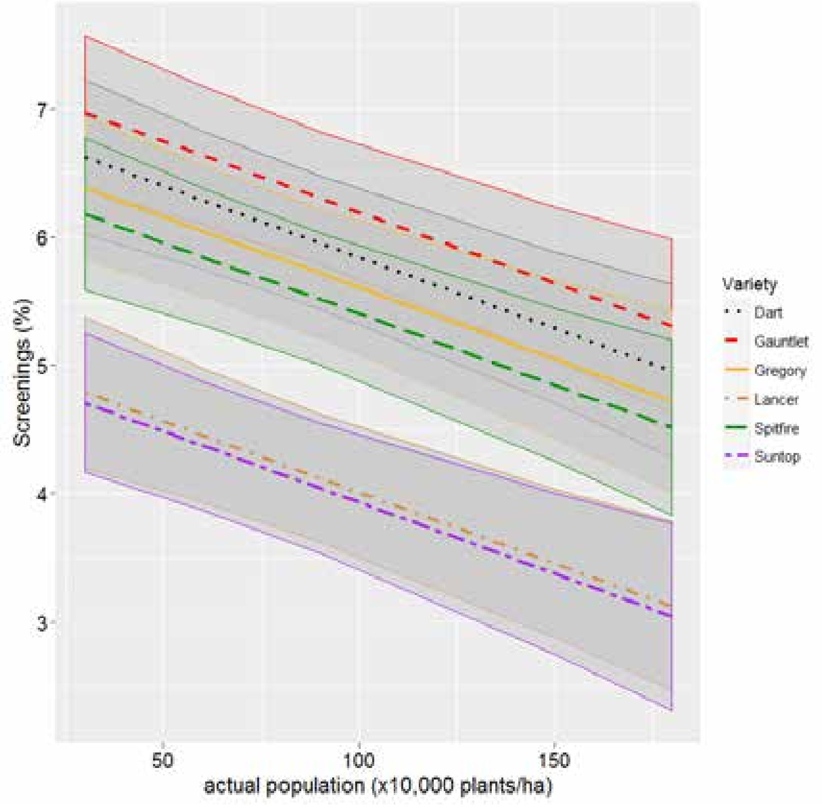

Figure 2. Percent grain screenings for varying population of six wheat varieties (5% represents the receival standard for premium grade wheat)

Grain screenings also improved significantly with increasing populations for all varieties tested. The difference was 0.1% reduction in screenings for every 90,000 plants/ha (Figure 2). This may be only a small improvement, but the site average was 5.3%, so required less than 0.5% reduction in screenings to achieve a $61/t increase in value (AUH2 @ $196/t to APH @ $257/t—Goondiwindi East, March 2017 cash price). At the site average yield of 4.3 t/ha this could equate to $262/ha extra grain value without any yield benefit.

High population (left) matured evenly for timely harvest; low population wheat with late tillers (right) delayed harvest

Implications for growers

This season had a long, cool and wet grain fill period, which allowed the plants in low populations to tiller vigorously and compensate for yield. As such only one of the six varieties tested had a yield penalty for dropping below the currently recommended population of 600,000 to 1,000,000 plants per hectare.

Regardless, there was still a financial benefit to maintaining these higher populations, as the improved grain quality (especially screenings) from the higher established populations has seen potential GrainCorp grading differences to the value of $61/t.

Establishment counts at this site also demonstrated decreasing establishment percentage for increasing plant densities. This would suggest that when targeting higher populations, or planting on wider rows (more plants per metre of row), planting rates may need to be increased slightly to compensate for the reduced establishment due to plant competition.

Acknowledgements

We would like to acknowledge and thank our co-operators who allow us to conduct these trials on their properties.

The Variety Specific Agronomy Packages (VSAP) program is co-funded by New South Wales Department of Primary Industries, the Grains Research and Development Corporation and the Department of Agriculture and Fisheries.

Seed supplied by Australian Grain Technologies, Advanta Seeds, Heritage Seeds and Seednet.

Trial details

Location:	35 km north of Goondiwindi
Crop:	Wheat
Soil type:	Poplar Box, Duplex soil
In-crop rainfall:	280 mm
Fertiliser:	30 kg/ha of Granulock Z®

Wheat: impact of population effect on the phenology and yield potential—Allora

Duncan Weir
Department of Agriculture and Fisheries

Research Questions: *Can changing target population have a significant effect on the phenology and yield potential of wheat? If so, are there any clear varietal differences which can be used to optimise yield potential?*

Key findings

1. Plant population directly impacts on crop yield and grain quality aspects including screenings and protein.
2. Achieving targeted populations is critical in optimising production outcomes.

Background

To optimise wheat yields in Queensland, it is generally recommended that established plant populations should be one million plants per hectare (100 plants per square metre), under most conditions.

Targeting this plant population can have a number of benefits, such as compensating for poor plant emergence, suppression of weeds through increased completion, and encouraging even flowering and harvest.

This trial continues on past research exploring the impact of plant populations on yield and grain quality as well as comparing the impact of plant population on different varieties under similar environmental conditions.

What was done

The trial was planted on 12 July 2016 using a double disc planter set up on 25 cm row spacings. Six varieties and five plant populations were planted in a randomised block design. Measurements taken throughout the trial included established populations, head emergence and flowering dates, plant height, and grain yield.

Varieties:

1. LongReach Dart⦶
2. LongReach Lancer⦶
3. LongReach Spitfire⦶
4. LongReach Gauntlet⦶
5. Suntop⦶
6. EGA Gregory⦶

Targeted populations:

1. 300,000 plants/ha
2. 600,000 plants/ha
3. 900,000 plants/ha
4. 1,200,000 plants/ha
5. 1,500,000 plants/ha

Results

Plant establishment varied from targeted populations (Table 1). Averaged across all varieties, percentage establishment reduced as planting rate increased from 85% (30 and 60 plants/m^2) to 69% (150 plants/m^2). An acceptable population spread was achieved across all treatments to allow analysis to be undertaken.

Table 1. Average established plant population per hectare

Targeted population (plants/ha)	LongReach Dart⦶	LongReach Gauntlet⦶	EGA Gregory⦶	LongReach Lancer⦶	LongReach Spitfire⦶	Suntop⦶
300,000	369,250	343,875	275,625	246,167	296,625	161,000
600,000	681,625	721,000	662,375	637,000	525,000	506,625
900,000	821,625	918,167	866,250	854,000	809,375	636,125
1,200,000	1,079,750	1,138,375	993,125	967,750	1,216,250	800,625
1,500,000	1,344,875	1,433,250	1,178,625	1,172,500	1,206,625	966,875

Table 2. Impact of plant population on flowering time (days to 50% flowering)

Target population (plants/ha)	LongReach Lancer$^{\phi}$	EGA Gregory$^{\phi}$	LongReach Gauntlet$^{\phi}$	Suntop$^{\phi}$	LongReach Spitfire$^{\phi}$	LongReach Dart$^{\phi}$
300,000	102	99	97	98	92	88
600,000	102	98	96	95	90	84
900,000	101	99	96	93	91	84
1,200,000	101	99	94	92	90	84
1,500,000	100	99	97	92	90	84

Table 3. Impact of plant population on plant height (cm)

Target population (plants/ha)	LongReach Dart$^{\phi}$	LongReach Gauntlet$^{\phi}$	EGA Gregory$^{\phi}$	LongReach Lancer$^{\phi}$	LongReach Spitfire$^{\phi}$	Suntop$^{\phi}$
300,000	86	84	99	81	93	98
600,000	91	86	103	84	94	102
900,000	91	86	105	83	97	104
1,200,000	89	91	102	82	94	106
1,500,000	90	91	104	85	98	106

Flowering time

Population had limited impact on time to flowering, although all varieties tended to flower later with low populations. Suntop$^{\phi}$ showed the greatest change varying by six days (Table 2). Time to flowering was significantly impacted by variety, ranging from an average of 101 days to flower for LongReach Lancer$^{\phi}$ to an average of 85 days to flower for LongReach Dart$^{\phi}$.

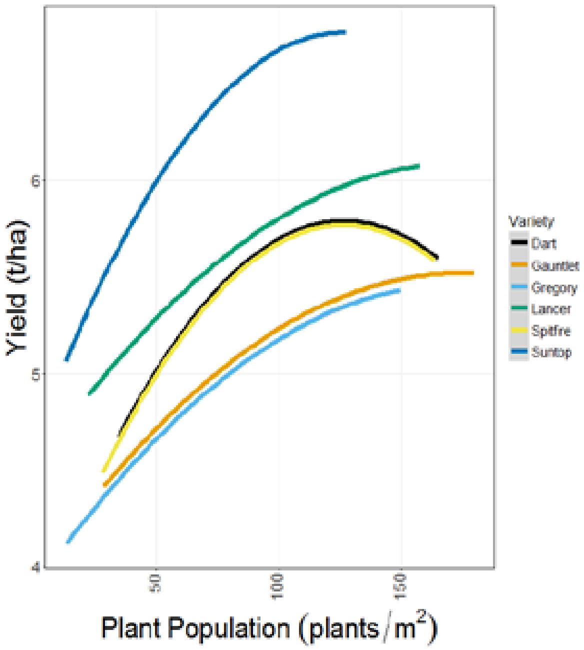

Figure 1. Yield response to population across all varieties

Plant height

Average plant height increased with population except LongReach Dart$^{\phi}$ and LongReach Lancer$^{\phi}$, which didn't show any major change after a population of 600,000 plants/ha (Table 3).

Yield

Population had a significant impact on yield for all varieties. Yields increased with increased plant populations however there was also a significant difference in response between varieties. Not only did actual yield differ between varieties but so did the plant population at which maximum yield was measured (Figure 1).

Suntop$^{\phi}$ yielded significantly better than all other varieties for all populations (Figure 1). However, following the varietal yield response analysis, varieties were split into two groups. For three varieties (LongReach Lancer$^{\phi}$, LongReach Gauntlet$^{\phi}$ and EGA Gregory$^{\phi}$), their response curve suggested that an optimum plant density would have been 1,750,000 plants/ha for this particular site (Table 4). Whereas for varieties LongReach Dart$^{\phi}$, LongReach Spitfire$^{\phi}$ and Suntop$^{\phi}$, analysis estimated that the maximum yield was achieved at a plant density of 1,270,000 plants/ha (Table 5).

Table 4. Predicted yield values and level of significance for varieties in cluster one at a plant population of 100 plants/m² (1,000,000 plants/ha)

Variety	Predicted Value	Standard Error	
LongReach Lancer$^{\phi}$	5.802	0.081	a
LongReach Gauntlet$^{\phi}$	5.23	0.092	b
EGA Gregory$^{\phi}$	5.175	0.08	b

Letters indicate significant differences between predicted yields between varieties LSD (P=0.05)

Table 5. Predicted yield values and level of significance for varieties in cluster two at a plant population of 100 plants/m² (1,000,000 plants/ha)

Variety	Predicted value	Standard error	
Suntop$^{\phi}$	6.675	0.085	a
LongReach Dart$^{\phi}$	5.693	0.083	b
LongReach Spitfire$^{\phi}$	5.673	0.085	b

Letters indicate significant differences between predicted yields between varieties LSD (P=0.05)

Grain qualities

Variety had a significant influence on protein levels (Table 6). LongReach Spitfire$^{\phi}$ had significantly higher proteins levels than all other varieties while the highest yielding variety Suntop$^{\phi}$ had the lowest protein level. As increasing population has increased yield (Figure 2), protein levels have reduced at the same rate.

A wheat plot ready for harvest

Table 6. Predicted protein levels of varieties at a population of 100 plants/m² (1,000,000 plants/ha)

Variety	Predicted value	Standard error	
LongReach Spitfire$^{\phi}$	12.089	0.26	a
LongReach Lancer$^{\phi}$	11.696	0.262	b
LongReach Gauntlet$^{\phi}$	11.586	0.264	bc
LongReach Dart$^{\phi}$	11.435	0.26	bc
EGA Gregory$^{\phi}$	11.299	0.26	cd
Suntop$^{\phi}$	11.021	0.263	d

Letters indicate significant differences between predicted protein levels between varieties LSD (P=0.05)

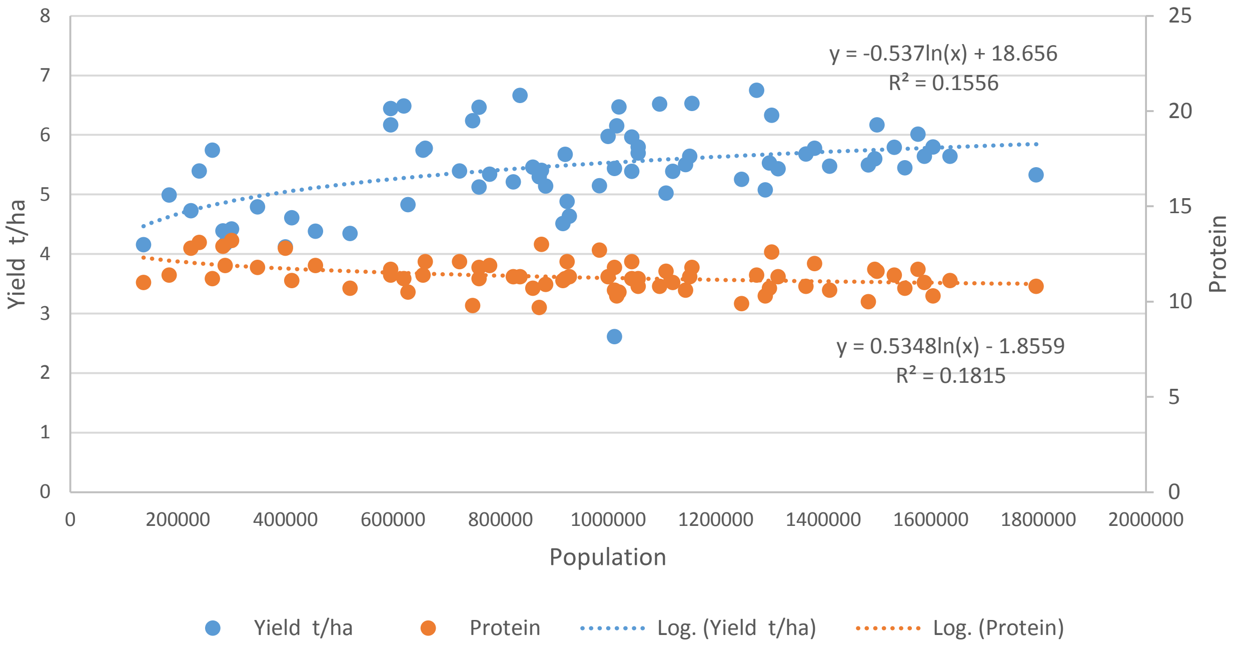

Figure 2. Response of protein levels and yield to increased populations

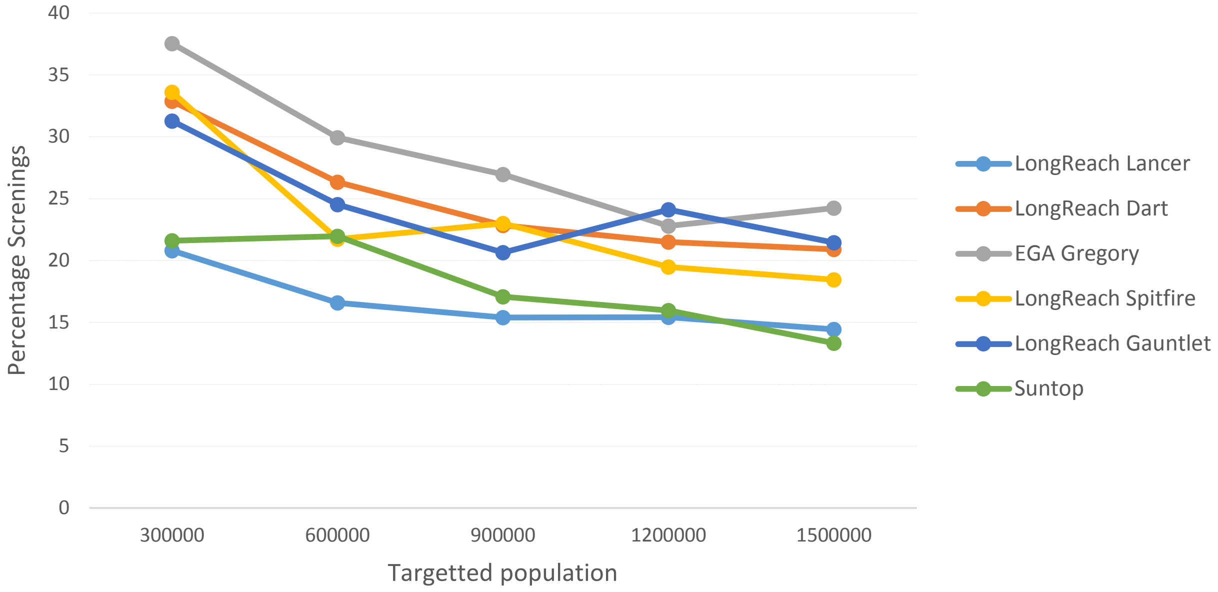

Figure 3. Percentage screening of each variety for targeted populations

Population has significantly impacted on the percentage of screening. Screenings have decreased with increased populations for all varieties (Figure 3). Variety has also had a significant effect on the level of screenings. EGA Gregory$^{\phi}$ having a significantly higher level of screenings than LongReach Lancer$^{\phi}$ and Suntop$^{\phi}$ which had the lowest levels.

Implications for growers

The trial was conducted under very favourable weather conditions as can be seen in the above average yield results, particularly at high plant populations. This needs to be considered when assessing the results and applying them to commercial crop production. There are however several important conclusions that can be drawn out.

In this environment, LongReach Lancer$^{\phi}$, LongReach Gauntlet$^{\phi}$ and EGA Gregory$^{\phi}$ require higher plant populations than Suntop$^{\phi}$, LongReach Dart$^{\phi}$ and LongReach Spitfire$^{\phi}$ to achieve optimum yield.

Achieving targeted plant population is not only critical in optimising crop yield potential but can also have a significant impact on grain quality aspects such as protein levels and screenings.

Increasing yield potential from higher populations may also increase the crop nitrogen requirement and should be taken into account to ensure protein levels are maintained.

Acknowledgements

We would like to thank our co-operators who allow us to conduct these trials on their properties.

The Variety Specific Agronomy Packages program is co-funded research between New South Wales Department of Primary Industries, the Grains Research and Development Corporation and the Department of Agriculture and Fisheries Regional Agronomy Network to complete six trials per year across the Queensland grain belt in 2015 and 2016.

Seed supplies from Australian Grain Technologies, Advanta Seeds, Heritage Seeds and Seednet.

Trial details

Location:	Allora, Queensland
Crop:	Wheat
Soil type:	Black Vertosol
In-crop rainfall:	273 mm
Fertiliser:	100 kg of urea was applied pre-plant by the grower and additional 50 kg of Granulock Z® at planting

Wheat: impact of population effect on the phenology and yield potential—Jambin

Douglas Lush
Department of Agriculture and Fisheries

Research Questions: *Can changing target population have a significant effect on the phenology and yield potential of wheat? If so, are there any clear varietal differences which can be used to optimise yield potential?*

Key findings

1. The Jambin site in 2016 didn't conform to our previous knowledge of yield increases in response to increases in plant population.
2. Inherent genetic traits had more impact on protein, test weight and screenings than did changes in plant population.

Background

It is generally accepted that for dryland wheat planting in usual Queensland conditions, 1,000,000 plants per hectare or 100 plants/m² is optimal. While targets are set by a weight of grain per hectare, plant populations can vary due to the size or the quality (percentage germination or vigour) of the seed used. What needs to be determined is the impact that a less than ideal plant population can have on aspects of the crop, or if overpopulating has any adverse impacts.

What was done

The plant population trial at Jambin was sown on 11 June 2016 with a five row planter with 36 cm row spacing.

Target populations were:

1. 300,000 plants / ha or 30 plants/m²
2. 600,000 plants /ha or 60 plants/m²
3. 900,000 plants /ha or 90 plants/m²
4. 1,500,000 plants /ha or 150 plants/m²

The varieties in order of increasing maturity from slow to quick were (2017 Queensland wheat varieties guide):

1. LongReach Lancerᶲ
2. EGA Gregoryᶲ
3. LongReach Gauntletᶲ
4. Suntopᶲ
5. LongReach Spitfireᶲ
6. LongReach Dartᶲ

Four crop attributes were measured; yield, test weight, protein and screenings.

Results

Unlike the other regional population trial sites in 2016, the yield response of varieties at Jambin was described by a straight line relationship. EGA Gregoryᶲ, Suntopᶲ, LongReach Lancerᶲ, LongReach Gauntletᶲ, and LongReach Dartᶲ all increased yield in response to population increase. In contrast, the response of LongReach Spitfireᶲ demonstrated a declining yield with increases in plant population (Figure 1). Confidence intervals for these regression lines are quite wide so trends need to be interpreted with care.

There was no significant link between plant population and test weight results. Varieties grouped together according to their test weight. LongReach Gauntletᶲ and LongReach Spitfireᶲ, had significantly higher screenings than EGA Gregoryᶲ and LongReach Dartᶲ (Table 1).

Table 1. Test weight results (kg/hL)

Genotype	mean	Standard error	
LongReach Gauntletᶲ	84.15	0.24	a
LongReach Spitfireᶲ	83.98	0.24	a
Suntopᶲ	83.76	0.24	ab
LongReach Lancerᶲ	83.64	0.24	ab
EGA Gregoryᶲ	83.31	0.24	b
LongReach Dartᶲ	83.17	0.24	b

Least Significant Difference (LSD) = 0.65

Screenings data showed no significant variation in response to different plant populations. A minor difference was noted for LongReach Dartᶲ when compared with the other varieties (Table 2).

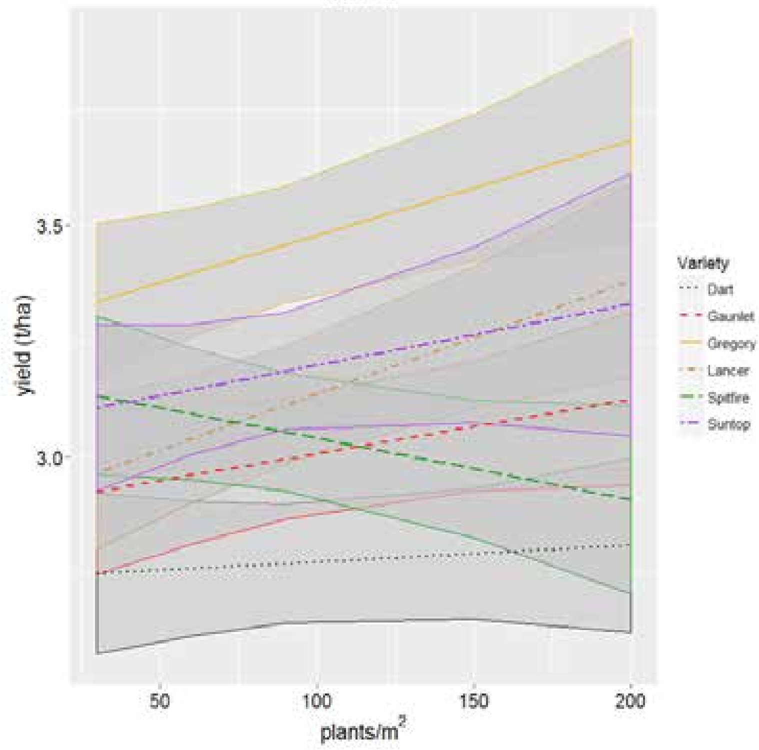

Figure 1. Yield responses to varying plant populations

Table 2. Screenings results (%)

Genotype	mean	Standard error	
LongReach Dartϕ	9.59	0.81	a
EGA Gregoryϕ	7.14	0.81	b
LongReach Spitfireϕ	6.95	0.81	b
LongReach Gauntletϕ	6.75	0.81	b
LongReach Lancerϕ	6.13	0.81	b
Suntopϕ	5.79	0.81	b

LSD = 2.03

Grain protein data showed no significant variation in response to different plant populations. A minor difference was noted for LongReach Lancerϕ when compared with the other varieties (Table 3).

Table 3. Protein results (%)

Genotype	mean	Standard error	
LongReach Lancerϕ	13.85	0.21	a
EGA Gregoryϕ	13.18	0.21	b
LongReach Spitfireϕ	13.17	0.21	b
LongReach Gauntletϕ	13.14	0.21	b
Suntopϕ	13.03	0.21	b
LongReach Dartϕ	12.84	0.21	b

LSD = 0.57

Implications for growers

While there was a general yield increase in response to higher plant populations the trend wasn't as conclusive as at other sites. However with five of the six varieties, a yield benefit would have been achieved by planting more seed rather than less.

Acknowledgements

The Variety Specific Agronomy Packages program is a continuation of co-funded research between New South Wales Department of Primary Industries and the Grains Research and Development Corporation. This work was contracted to the Department of Agriculture and Fisheries Regional Agronomy Network to complete six trials per year across the Queensland grain belt in 2015 and 2016.

Seed supplies from Australian Grain Technologies, Advanta Seeds, Heritage Seeds and Seednet for the supply of seed for the various trials.

We would also like to acknowledge and thank our co-operators who allow us to conduct these trials on their private properties.

Trial details

Location:	Jambin
Crop:	Wheat
Soil type:	Vertosol
In-crop rainfall:	242.8 mm
Fertiliser at planting (11 June 2016):	40 kg/ha urea 40 kg/ha Granulock Z®
Harvest:	18 October 2016

Wheat population trials at Jambin

Wheat: impact of population effect on the phenology and yield potential—Brookstead

Douglas Lush
Department of Agriculture and Fisheries

RESEARCH QUESTIONS: *Can changing target population have a significant effect on the phenology and yield potential of wheat? If so, are there any clear varietal differences which can be used to optimise yield potential?*

Key findings

1. Yield increased with increasing plant population to approximately 1 million plants per hectare or 100 plants/m^2 (there is some variation between varieties). At this point yield became reasonably stable for all varieties tested until 1.5 million plants per hectare, then yield started to decline.
2. The days from planting to flowering reduces for quicker varieties but not the slower varieties.

Background

It is generally accepted that for dryland wheat planting in usual Queensland conditions, 1,000,000 plants per hectare or 100 plants/m^2 is optimal. While targets are set by a weight of grain per hectare plant populations can vary due to the size or the quality (percentage germination or vigour) of the seed used. What needs to be determined is the impact that a less than ideal plant population can have on aspects of the crop, or if overpopulating has any adverse impacts.

What was done?

The plant population trial at Brookstead was sown on 1 July 2016 with a five row planter with 36 cm row spacing.

Target populations were:

1. 300,000 plants / ha or 30 plants/m^2
2. 600,000 plants /ha or 60 plants/m^2
3. 900,000 plants /ha or 90 plants/m^2
4. 1,500,000 plants /ha or 150 plants/m^2

The varieties in order of increasing maturity from slow to quick were (2017 Queensland wheat varieties guide):

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

Six crop attributes were measured; yield, test weight, protein, screenings, height, and days to flowering.

Results

Days to flowering was altered slightly due to the influence of plant population; the higher the population, generally the quicker the varieties reached 50% flowering (Figure 1). The slower varieties (LongReach Lancer$^{\phi}$ and EGA Gregory$^{\phi}$),

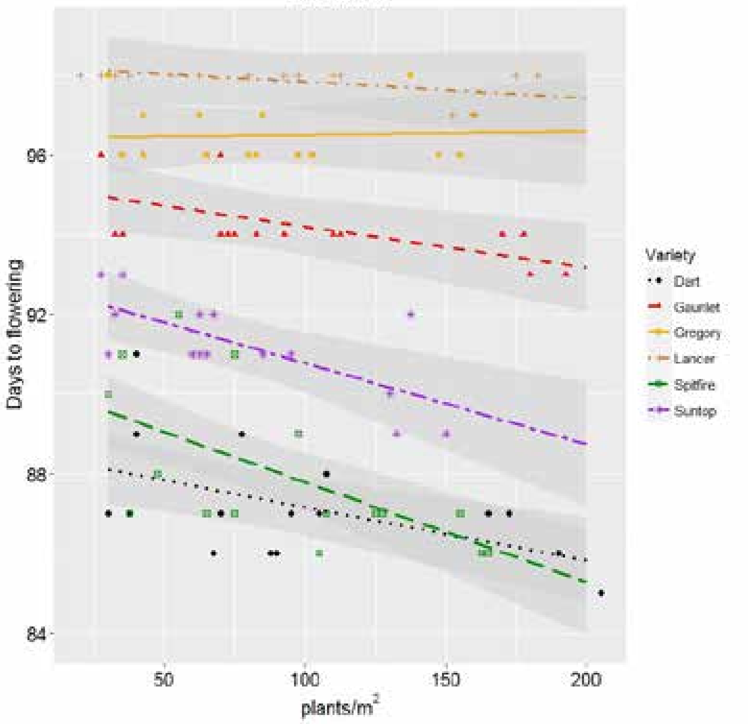

Figure 1. Changes in days to flowering in response to varying plant populations

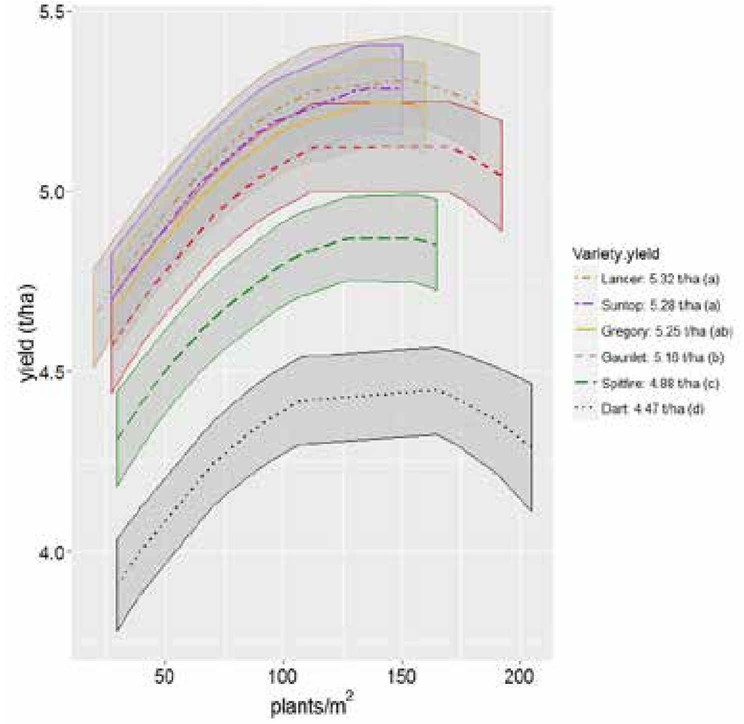

Figure 2. Varietal yield responses to varying plant populations

had a relatively flat response to plant population. The quicker varieties, LongReach Gauntlet$^{\phi}$, Suntop$^{\phi}$, LongReach Spitfire$^{\phi}$ and LongReach Dart$^{\phi}$ have shorter days to flowering with higher populations.

The lowest populations recorded the lowest yields at the Brookstead site. As population increased from 25 to 75 plants/m², the yield steadily increased. Between 100 and 150 plants/m² the yield tends to be reasonable stable. Above 150 plants/m² the yield appears to reduce a little, however further assessment of populations above 150 plants/m² would be required to confirm this result (Figure 2).

The varieties separated along genetic yield potential to a degree. LongReach Lancer$^{\phi}$, Suntop$^{\phi}$, EGA Gregory$^{\phi}$ and LongReach Gauntlet$^{\phi}$ group together in this trial, LongReach Spitfire$^{\phi}$ and LongReach Dart$^{\phi}$ were significantly lower yielding.

Results from the test weight analysis presented very similar curves to the yield data (Figure 3).

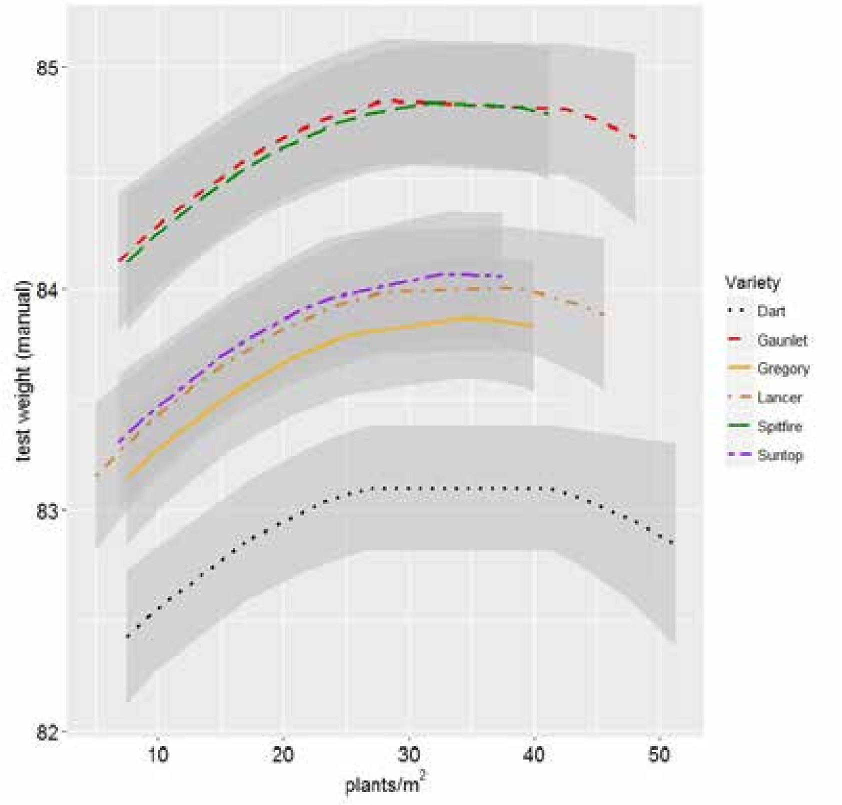

Figure 3. Test weight responses to varying yield populations

Test weight tended to increase in a similar fashion as it is a component of yield. Yet at the same time the varieties separated in test weight. LongReach Gauntlet$^{\phi}$ and LongReach Spitfire$^{\phi}$ had significantly higher test weights than Suntop$^{\phi}$, LongReach Lancer$^{\phi}$ and EGA Gregory$^{\phi}$. LongReach Dart$^{\phi}$ was significantly lower again.

Screenings describe very different responses depending on which variety you assess. LongReach Dart$^{\phi}$, LongReach Spitfire$^{\phi}$, Suntop$^{\phi}$ and LongReach Gauntlet$^{\phi}$ all had significantly lower screenings for higher plant populations (Figure 4). However there was no significant relationship between screenings and plant population for EGA Gregory$^{\phi}$ and LongReach Lancer$^{\phi}$. The slope of the lines describes the relationship between screenings and plant population.

No significant interactions between plant population and grain protein or plant population and height were observed. The variation in grain protein and height are a function of genetic variation.

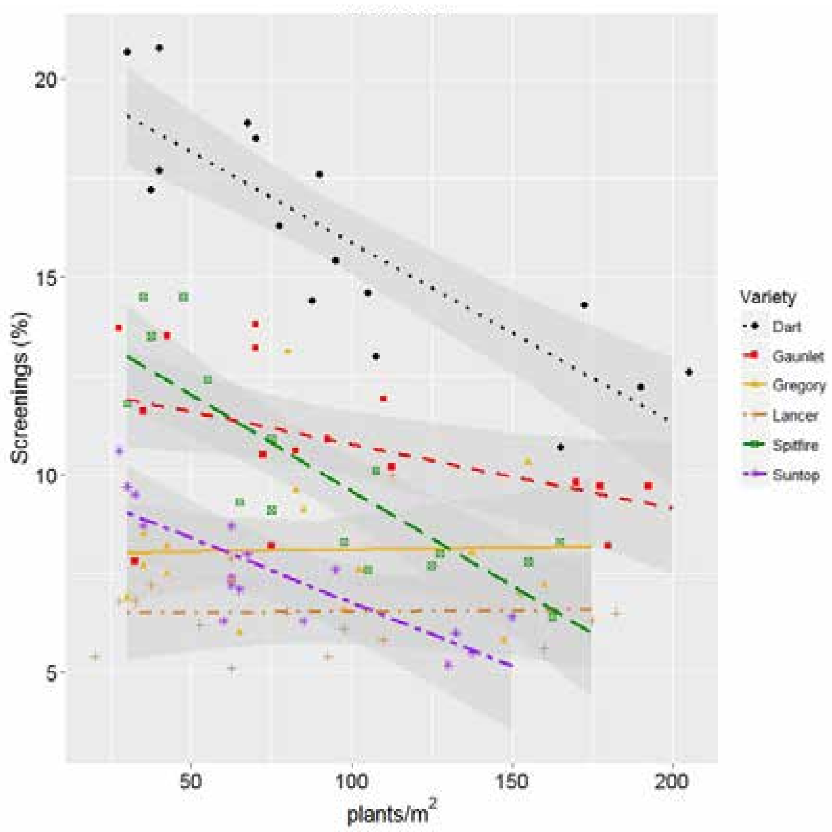

Figure 4. Percentage screenings in response to varying plant populations

Table 1. Grain protein results (%)

Genotype	mean	Standard error	
LongReach Spitfire$^{\Phi}$	13.89	0.05	a
LongReach Lancer$^{\Phi}$	13.63	0.05	b
LongReach Dart$^{\Phi}$	13.40	0.05	c
LongReach Gaunlet$^{\Phi}$	13.12	0.05	d
EGA Gregory$^{\Phi}$	12.59	0.05	e
Suntop$^{\Phi}$	12.22	0.05	f

LSD = 0.13

Table 2. Plant height results (cm)

Variety	mean	Standard error	
Suntop$^{\Phi}$	86.88	0.62	a
EGA Gregory$^{\Phi}$	85.63	0.62	a
LongReach Spitfire$^{\Phi}$	74.31	0.62	b
LongReach Gaunlet$^{\Phi}$	72.19	0.62	c
LongReach Dart$^{\Phi}$	70.13	0.62	d
LongReach Lancer$^{\Phi}$	69.75	0.62	d

LSD = 1.421

Implications for growers

From the data that has been gathered from many sites in the past two years it is evident that there is a yield response linked to increasing plant population. The response varies from site to site and for varieties but is overall reasonably consistent. Other attributes are less consistent however.

Acknowledgements

The Variety Specific Agronomy Packages program is a continuation of co-funded research between New South Wales Department of Primary Industries and the Grains Research and Development Corporation. This work was contracted to the Department of Agriculture and Fisheries Regional Agronomy Network to complete six trials per year across the Queensland grain belt in 2015 and 2016.

Seed supplies from Australian Grain Technologies, Advanta Seeds, Heritage Seeds and Seednet for the supply of seed for the various trials.

We would also like to acknowledge and thank our co-operators who allow us to conduct these trials on their private properties.

Trial details

Location:	Brookstead
Crop:	Wheat
Soil type:	Vertosol
In-crop rainfall:	291.4 mm
Pre-plant fertiliser (March 2016):	230 kg/ha urea
Fertiliser at planting (1 July 2016):	40 kg/ha Granulock® 12Z (Zn 2%)
Harvest:	30 November 2016

Wheat: impact of population effect on the phenology and yield potential—Meandarra

Douglas Lush
Department of Agriculture and Fisheries

***Research Questions:** Can changing target population have a significant effect on the phenology and yield potential of wheat? If so, are there any clear varietal differences which can be used to optimise yield potential?*

Key findings

1. No negative yield performance in response to increasing plant population was noticed at the Meandarra site until 2 million plants per hectare was achieved.
2. This negative influence on yield was only recorded for LongReach Gauntlet⦶.

Background

It is generally accepted that for dryland wheat planting in usual Queensland conditions, 1,000,000 plants per hectare or 100 plants/m^2 is optimal. While targets are set by a weight of grain per hectare plant populations can vary due to the size or the quality (percentage germination or vigour) of the seed used. What needs to be determined is the impact that a less than ideal plant population can have of aspects of the crop, or if overpopulating has any adverse impacts.

What was done?

The plant population trial at Meandarra was sown on the 14 June 2016 with a five row planter with 36 cm row spacing.

Target populations were:

1. 300,000 plants / ha or 30 plants/m^2
2. 600,000 plants /ha or 60 plants/m^2
3. 900,000 plants /ha or 90 plants/m^2
4. 1,500,000 plants /ha or 150 plants/m^2

The varieties in order of increasing maturity from slow to quick were (2017 Queensland wheat varieties guide):

1. LongReach Lancer⦶
2. EGA Gregory⦶
3. LongReach Gauntlet⦶
4. Suntop⦶
5. LongReach Spitfire⦶
6. LongReach Dart⦶

Results

Meandarra had a significant quadratic response for yield across the range of plant populations (Figure 1). In contrast with our expected response there was no obvious decline in yield response when a threshold population was reached. The only exception was LongReach Gauntlet⦶, which demonstrated a slight reduction in yield between 180 and 250 plants/m^2.

There was no significant link between plant population and test weight results. There were some significant differences between the varieties, LongReach Spitfire⦶ and Suntop⦶ were similar and significantly higher than LongReach Gauntlet⦶, LongReach Dart⦶ and EGA Gregory⦶ (Table 1).

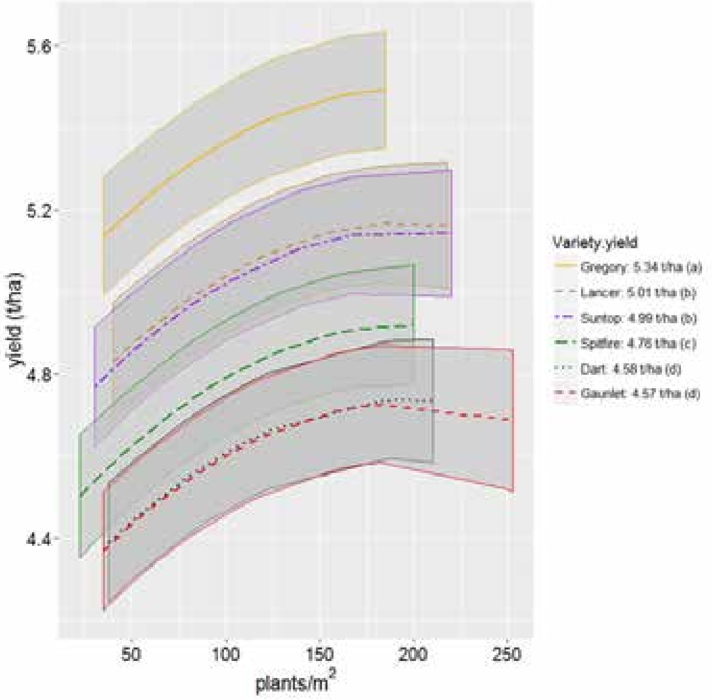

Figure 1. Yield responses to varying plant populations

Table 1. Test weight results (kg/hL)

Genotype	mean	Standard error	
LongReach Spitfire⦶	83.64	0.17	a
Suntop⦶	83.24	0.17	ab
LongReach Lancer⦶	83.01	0.17	bc
EGA Gregory⦶	82.67	0.17	cd
LongReach Dart⦶	82.21	0.17	de
LongReach Gaunlet⦶	82.20	0.16	e

Least Significant Difference (LSD) = 0.47

Percentage screenings data described different patterns; LongReach Gauntlet⦶ and LongReach Dart⦶ increased slightly with increasing plant population. Suntop⦶, EGA Gregory⦶ and LongReach Lancer⦶ decreased slightly with increasing plant population and LongReach Spitfire⦶ decreased at a much greater rate.

No significant interactions between plant population and height were observed (Table 2). Varieties did separate themselves according to height, EGA Gregory⦶ and Suntop⦶ were significantly taller than the other varieties. LongReach Lancer⦶ and LongReach Gauntlet⦶ were significantly shorter than all the other varieties.

Table 2. Plant height results (cm)

Variety	mean	Standard error	
EGA Gregory⦶	95.63	1.15	a
Suntop⦶	94.81	1.15	a
LongReach Spitfire⦶	84.50	1.15	b
LongReach Dart⦶	78.98	1.18	c
LongReach Lancer⦶	73.15	1.15	d
LongReach Gaunlet⦶	73.06	1.15	d

LSD = 2.70

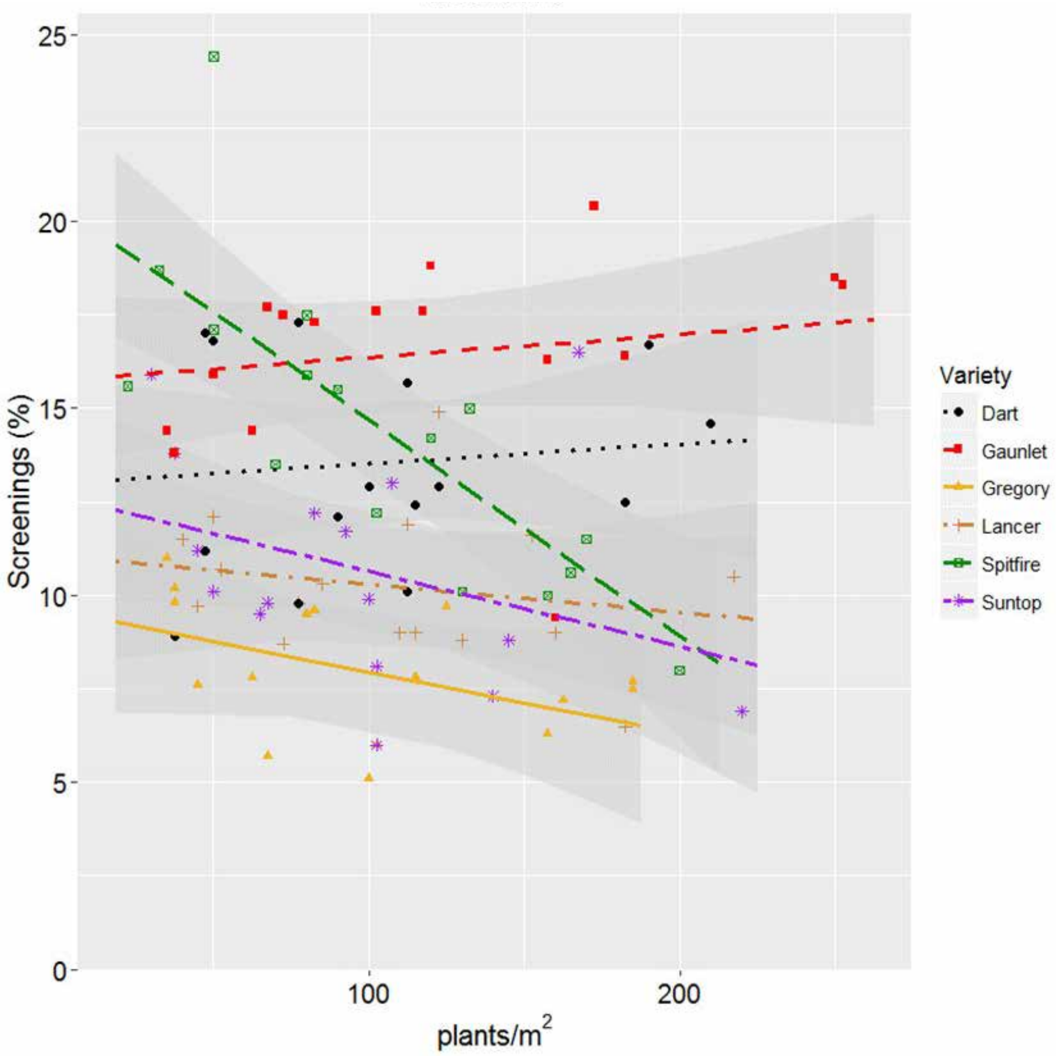

Figure 2. Percentage screenings in response to varying plant populations

No significant interactions between plant population and grain protein were observed (Table 3). LongReach Spitfire$^{\phi}$ and LongReach Dart$^{\phi}$ had significantly higher grain protein than the other varieties and EGA Gregory$^{\phi}$ and Suntop$^{\phi}$ were significantly the lowest.

Table 3. Grain protein results (%)

Genotype	mean	Standard error	
LongReach Spitfire$^{\phi}$	15.01	0.17	a
LongReach Dart$^{\phi}$	14.83	0.17	a
LongReach Lancer$^{\phi}$	14.20	0.17	b
LongReach Gaunlet$^{\phi}$	13.95	0.17	b
EGA Gregory$^{\phi}$	13.03	0.17	c
Suntop$^{\phi}$	12.82	0.17	c

LSD = 0.32

Implications for growers

At the Meandarra site in 2016 plant populations approaching two million plants per hectare provided the greatest yield performance. Therefore in this situation heavy planting rates would not have been detrimental to variety performance.

Acknowledgements

The Variety Specific Agronomy Packages program is a continuation of co-funded research between New South Wales Department of Primary Industries and the Grains Research and Development Corporation. This work was contracted to the Department of Agriculture and Fisheries Regional Agronomy Network to complete six trials per year across the Queensland grain belt in 2015 and 2016.

Seed supplies from Australian Grain Technologies, Advanta Seeds, Heritage Seeds and Seednet for the supply of seed for the various trials.

We would also like to acknowledge and thank our co-operators who allow us to conduct these trials on their private properties.

Trial details

Location:	Meandarra
Crop:	Wheat
Soil type:	Vertosol
In-crop rainfall:	264.5 mm
Fertiliser at planting (14 June 2016):	120 kg/ha urea 40 kg/ha Granulock Z®
Harvest:	9 November 2016

Wheat population trials at Meandarra

Wheat: impact of varying nitrogen treatments across different varieties and maturities—Emerald

Darren Aisthorpe and Ellie McCosker
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. All varieties showed an increased protein response to additional nitrogen.
2. Suntop$^{\phi}$ was the only variety to provide a positive yield response to nitrogen treatments in a high starting nitrogen scenario, however there were significant yield differences between varieties.
3. Application of excessive nitrogen for the amount of water available can give a yield penalty.

Background

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

In the Queensland Grains Research—2015 publication, the general trial observation was that “Even at high N conditions there was a significant protein response between varieties, but not across N treatments.” It was planned to replicate the trial in 2016 to see if the findings across varieties would be consistent.

What was done?

The trial was planted 18 May 2016 on 25 cm row spacings with Boss TX45 parallelogram, fitted with double disc opener shanks and covering press wheel behind. There was a considerable trash load from a previous summer crop in the field, and although it had been mulched, the stubble caused hair pinning.

Six nitrogen rates:

1. Nil
2. 60% of yield potential
3. 80% of yield potential
4. Spilt application of 100% (60% at planting and 40% spread on at flag emergence)
5. 100% of yield potential
6. 150% of yield potential

Five varieties:

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

Table 1. Calculated N treatments applied

Treatment	Predicted yield (t/ha)	Total N required (kg/ha)	Less current N (kg/ha)	N applied at planting (kg/ha)	N applied late tillering (kg/ha)
Nil	2.9	108	108	0	0
60% YP	3.2	119	108	11	0
80% YP	3.9	145	108	37	0
100% YP	4.5	168	108	60	0
100% YP Split	4.5	168	108	11	49
150% YP	6.7	250	108	142	0

The target N rates to achieve the calculated yield targets based on available water at planting (150 mm) were applied via a combination of liquid and granular urea at the time of planting (Table 1).

The N rates were slightly recalibrated from the 2015 trial, and row spacing narrowed from 50 cm to 25 cm, to maximise established populations and yield. Planting conditions were testing, with high trash loads and inherently high starting nitrogen levels (in excess of 108 kg/ha of nitrogen to a depth of 90 cm).

Observations taken in-crop included plant available water (PAW) at planting and harvest, emergence plant counts, flowering dates and plant height post grain fill. The trial was harvested on 11 October 2016 with yield and moisture recorded in all plots at harvest. Subsamples were collected from all plots, which were later used to perform grain quality assessments including; protein (%), screenings (%) and test weight.

Results

Plant counts were conducted approximately 10 days after planting, however due to the hair pinning issues, establishment was less than ideal across all treatments (Figure 1). After additional irrigation, emergence did improve, however it was noticed that 150% yield potential (YP) high nitrogen treatments did not achieve consistently acceptable populations across any variety. Plant counts indicated that N reduced establishment, once additional nitrogen applied exceeded 40 kg N/ha. This was despite the N being applied as a separate operation before planting, offset from the seed row.

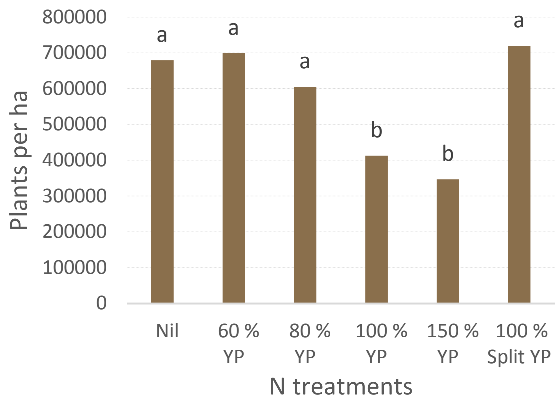

Figure 1. Average plants established after 10 days, across all varieties for each of the N treatments
Bars with different letters are significantly different ($P<0.001$)

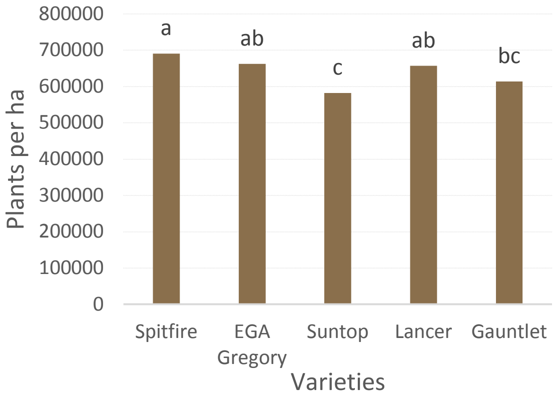

Figure 2. Average plants established after 10 days, across all treatments, excluding 150% YP
Bars with different letters are significantly different ($P<0.05$)

To try and mitigate the low population effect caused by the high N treatments, a second statistical analysis was conducted of the trial data, removing plots with outlier populations below 180,000 plants per hectare and the 150% YP treatment completely, enabling a clearer response curve across some of the published results (Figure 2). Varietal variation in establishment could then be compared which wasn't possible when the low population treatments were included.

Nitrogen application had no significant effect ($p<0.05$) on flowering dates, yield, plant height or water use efficiency of the trial. All treatments on average flowered close to the 90 days after sowing, yield remain constant at 4300 kg/ha, give or take 100 kg/ha and water use efficiency (WUE) averaged 10.5 kg/ha/mm despite the wide range of N treatments applied.

There was no significant differences between the analysis with or without the low population of 150% YP treatments, therefore the analysis including the low population plots is shown (Table 2) to provide a clearer indication of what effect N rates can have on grain qualities, no matter what the established population was.

The N treatment effect became apparent when grain quality attributes are assessed. Protein increased for increasing N rate, however screenings have also increased for the High N plots, indicating they became water-limited for the given amount of N. Soil water measurements taken at harvest support this, as the crop had utilised all the water it had available to it, with an average of only 7 mm of PAW still available to the plants.

Table 2. Grain quality effects from nitrogen or variety interactions ANOVA table

	Grain protein (%)	Test weight (kg/hL)	Screenings (%)	1000 seed weight (g)
N Rates (R)	***	***	***	**
Nil	12.6 cd	***	**	***
60% YP	12.0 d	79.9 a	3.9 c	37.8 ab
80% YP	13.0 bc	80.0 a	3.8 c	38.6 a
100% YP	13.3 ab	78.1 b	5.1 bc	35.4 cd
150% YP	13.9 a	76.4 c	6.6 ab	34.4 d
100% YP Split	13.0 bc	75.9 c	7.2 a	34.0 d
ave. s.e.d.	0.3	79.1 ab	4.5 c	36.7 bc
Variety (V)	***	***	***	***
LongReach Spitfire⁽ᵈ⁾	13.5 a	81.3 a	3.1 d	41.3 a
EGA Gregory⁽ᵈ⁾	12.9 b	76.2 d	6.4 b	33.8 c
Suntop⁽ᵈ⁾	11.8 c	80.1 a	3.8 d	40.4 b
LongReach Lancer⁽ᵈ⁾	13.3 a	78.2 c	5.0 c	32.9 d
LongReach Gauntlet⁽ᵈ⁾	13.3 a	75.4 d	7.6 a	32.5 d
ave. s.e.d.	0.1	0.5	0.4	0.3

Different letters indicate significant difference with the column, the number of * indicate the strength of the significance (n.s. - not significant (P >0.10); * - P <0.05; ** - P <0.01; *** - P <0.001).
Ave. s.e.d = Average Standard Error of Difference

There was a significant difference in protein as N rates increased across varieties. LongReach Spitfire⁽ᵈ⁾ again showed its ability to produce a higher protein grain than the similar maturity Suntop⁽ᵈ⁾ (Figure 3), however when you look at other attributes such as screenings, test weight and 1000 seed weight (Table 2), there wasn't a great difference between them in 2016. EGA Gregory⁽ᵈ⁾ had the widest protein response of any of the varieties, however its yield response was almost flat, when compared to Suntop⁽ᵈ⁾ or LongReach Spitfire⁽ᵈ⁾ (Figure 3).

The yield response from LongReach Spitfire⁽ᵈ⁾, LongReach Lancer⁽ᵈ⁾ and LongReach Gauntlet⁽ᵈ⁾ were almost identical with all three varieties appearing to decrease yield as protein increased (Figure 4). This would indicate sufficient N was available for the given water available to the crop for these varieties, however there were statistical differences in yield performance between the three (Table 3).

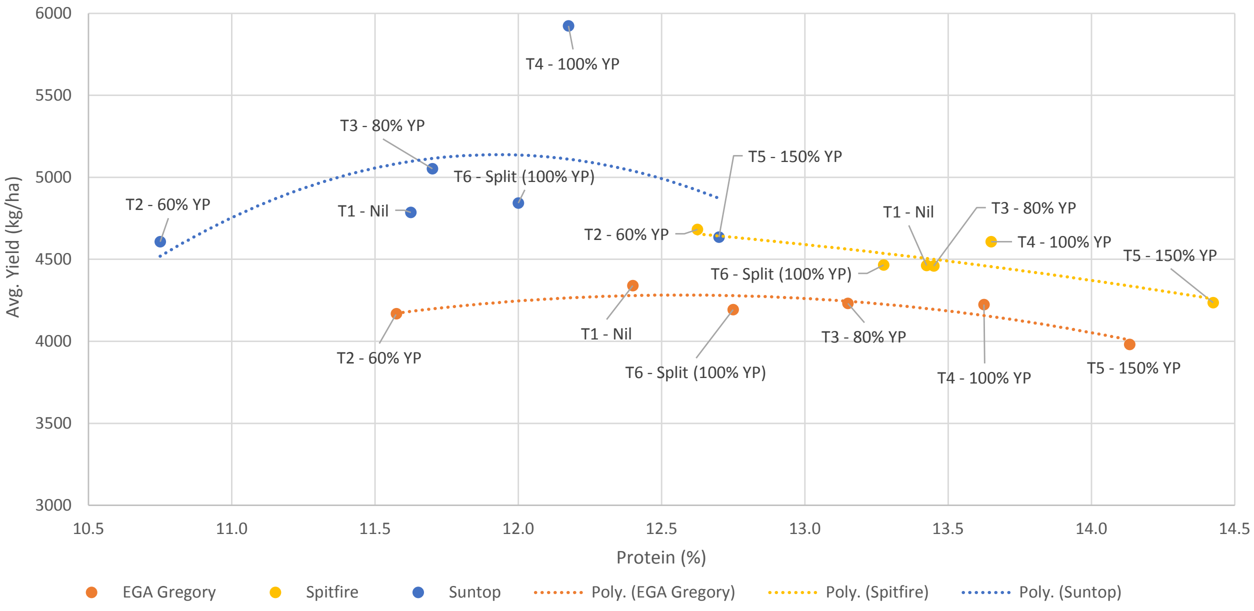

Figure 3. Yield and protein response to nitrogen treatments applied to Suntop⁽ᵈ⁾, LongReach Spitfire⁽ᵈ⁾ and EGA Gregory⁽ᵈ⁾

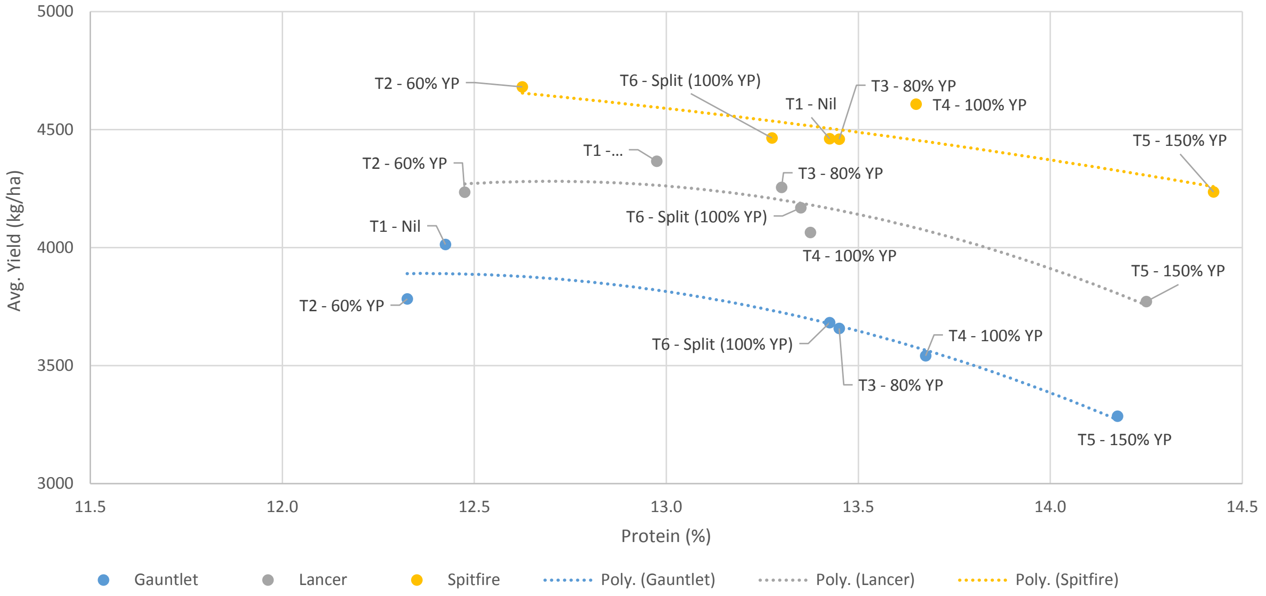

Figure 4. Yield and protein response to nitrogen treatments applied to LongReach Lancer$^{\phi}$, LongReach Spitfire$^{\phi}$ and LongReach Gauntlet$^{\phi}$

Implications for growers

Grain protein of 11.5% and above indicates that N was not limiting the yield potential (Cox, H. and Strong, W. (2009). *The Nitrogen Book,* page 39). This level of protein was achieved by the control or nil treatment, so no significant yield benefit was expected, however as available N increased in higher treatments, so too did the protein.

Trying to match nitrogen rates at the start of the season is always a challenge, particularly if the profile is not full or you are reliant on in-crop rain to get through the season. For this particular trial, the only variety that showed a significant yield increase as a result of nitrogen application was Suntop$^{\phi}$, which would indicate that if planting into a high N site, it may be the preferred variety to maximise yield, however that yield response could come at a varietal protein penalty when compared to similar maturity varieties.

Acknowledgements

The Variety Specific Agronomy Packages program is a continuation of co-funded research between New South Wales Department of Primary Industries and the Grains Research and Development Corporation. This work was contracted to the Department of Agriculture and Fisheries Regional Agronomy Network to complete six trials per year across the Queensland grain belt in 2015 and 2016.

Seed supplies from Australian Grain Technologies, Advanta Seeds, Heritage Seeds and Seednet for the supply of seed for the various trials.

Table 3. Varietal effect across all nitrogen treatments (excluding 150%YP and low population plots)

Variety (V)	Population per ha		Days to flowering		Yield at 12.5%		WUE	
	*		***		***		***	
LongReach Spitfire$^{\phi}$	690,408	a	78.7	a	4535	b	10.99	b
EGA Gregory$^{\phi}$	662,075	ab	97.0	b	4231	c	10.25	c
Suntop$^{\phi}$	582,137	c	78.6	a	4819	a	11.67	a
LongReach Lancer$^{\phi}$	656,669	ab	97.2	b	4249	c	10.30	c
LongReach Gauntlet$^{\phi}$	614,002	bc	97.0	b	3775	d	9.15	d
ave. s.e.d.	36,744		0.5		86		0.21	

Different letters indicate significant difference with the column, the number of * indicate the strength of the significance (* - P <0.05; ** - P <0.01; *** - P <0.001).
Ave. s.e.d = Average Standard Error of Difference

Trial details

Location:	Field 5, Block 12 at Queensland Agricultural Training College, Emerald
Crop:	Wheat
Soil type:	Grey Cracking Vertosol with a water holding capacity in excess of 230 mm
In-crop rainfall:	The trial site had PAW of 92 mm down to 90 cm at the time of planting. An additional 75 mm of water was applied post emergence, on 27 May, to lift the starting water up to the target PAW of 150 mm. There was a total of 228 mm of in-crop rainfall received, predominately during June and July (Figure 5). An additional 50 mm was applied on 16 August around flowering/early grain fill as overhead sprinkler irrigation
Fertiliser:	Starting N on the site was 108 kg/ha with N treatments applied as described in the 'What was done' section. 30 kg/ha of Granulock Z® was also applied with the seed at planting

Measuring plot lengths

Harveting the trial

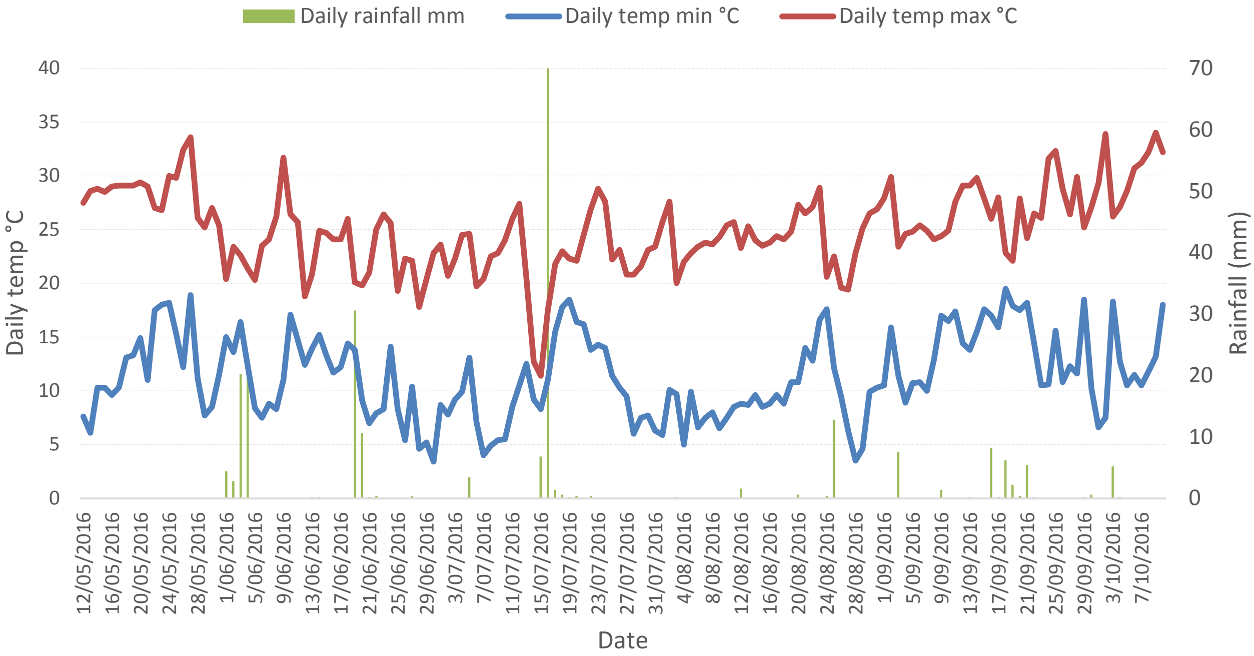

Figure 5. Weather data (temperatures and rainfall) for trial site

Wheat: impact of varying nitrogen treatments across different varieties and maturities—Goondiwindi

Andrew Erbacher
Department of Agriculture and Fisheries

Research Question: *Is there a varietal difference in yield and protein response to nitrogen application in south west Queensland to optimise yield potential?*

Key findings

1. Increasing nitrogen increased grain yield and protein.
2. Applying nitrogen as a split application has provided a small grain protein benefit with no effect on grain yield.
3. Varietal preference for higher grain yield or protein was observed.

Background

A number of trials conducted as part of the Variety Specific Agronomy Package (VSAP) work by the NSW Department of Primary Industries have shown not all varieties respond the same way to increased available nitrogen (N). Some varieties tend to increase yield first at the expense of protein, others reverse this trend, 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 various Queensland conditions.

What was done

The site was located 30 km north of Goondiwindi on brigalow scrub soil (Vertosol) and had chickpea as the previous crop. There was 110 mm of plant available water (PAW) at planting. Predicta B tests detected root lesion nematodes (*Pratylenchus neglectus*), but below levels likely to cause a yield reduction in wheat.

Soil nitrate tests for this paddock showed 86 kg N/ha to 90 cm depth prior to planting. The urea was pre-applied using a double disc planter on 25 cm row spacings on 23 May, then planted after the next rainfall event using the same planter. Five varieties were planted on 30 May 2016 into each of the six nitrogen treatments, with a target population of 1 million plants/ha.

The varieties in order of increasing maturity from slow to quick were (2017 Queensland wheat varieties guide):

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

Nitrogen rates were set based on an estimated site grain yield potential of 3.5 t/ha at 12% protein (Table 1):

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

Table 1. Calculated nitrogen treatments applied

Treatment	Budget yield (t/ha)	Total nitrogen required (kg N/ha)	Nitrogen applied pre-plant (kg N/ha)	Nitrogen applied in-crop (kg N/ha)
Control	0	0	0	0
50% YP	1.8	66	0	0
75% YP	2.6	99	13	0
100% YP	3.5	132	46	0
150% YP	5.3	198	112	0
100% split YP	3.5	132	23	23

(86 kg N/ha was available at the time of planting)

Split application nitrogen was surface applied as urea on 9 August. Crop stage was late tiller, with the earliest heads emerging two weeks later.

Results

A cool and wet spring (240 mm rainfall in September) meant this trial yielded well, with a trial average yield of 5.4 t/ha and maximum individual plot yield of 6.3 t/ha. Despite the higher than expected yields, the unfertilised treatments achieved 13% protein. This was possible because of a bulge of nitrogen below the budgeting depth, with 125 kg N/ha, in the 90-150 cm zone.

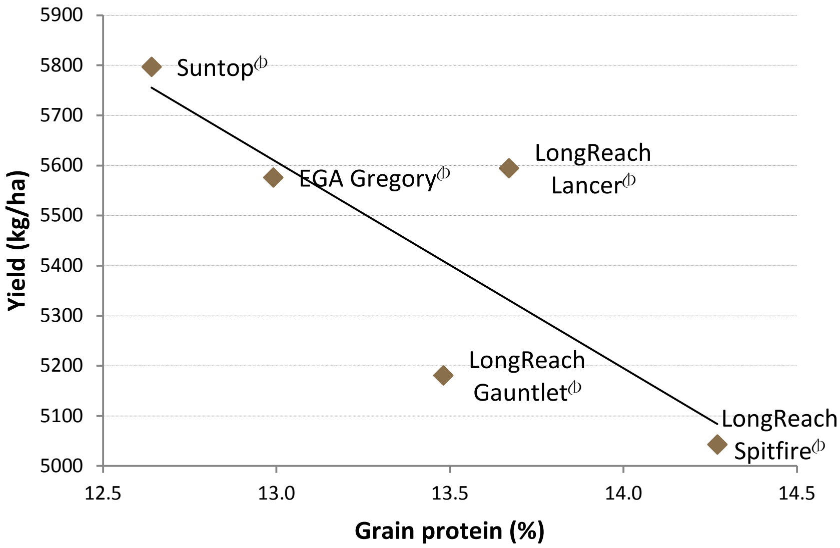

Figure 1. Dilution effect of wheat varieties, with decreasing yield for increasing protein

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

With only 13 kg N/ha (30kg urea/ha) applied, the 75% YP treatments were not significantly different to the un-fertilised plots, for any of the parameters measured (Table 2).

The higher rates of fertiliser did provide significant increases in grain yield. 100% YP either applied upfront or split, both yielded the same, however the split application did provide a small lift in grain protein. The highest rate of nitrogen (150% YP) provided an additional lift in grain yield and protein.

Grain quality (screenings, test weight and seed size) were not affected by any of the nitrogen treatments.

The top yielding varieties in this trial were Suntop⌽, followed by EGA Gregory⌽ and LongReach Lancer⌽. For Suntop⌽ and EGA Gregory⌽, the additional 100 kg N/ha in 150% YP was required to achieve the protein for the APH grade. The other three varieties were able to achieve this grading without the addition of any extra nitrogen. When comparing the nitrogen removal rates it is evident that for four of the varieties, the protein differences is a dilution effect from increasing yield. LongReach Lancer⌽ is the only variety to vary from this trend, producing higher protein for its relative yield (Table 2, Figure 1).

Table 2. Crop data

	Population (plants/m²)		Yield at 12.5% (kg/ha)		Grain protein (%)		N removed (kg/ha)	
N Treatments (R)	**n.s.**		*******		******		*******	
Nil and 50%	89.4		5145	c	13.0	b	113.7	c
75%	92.4		5145	c	13.3	b	116.0	c
100%	91.8		5538	b	13.2	b	124.7	b
150%	88.9		5804	a	14.0	a	136.9	a
Split	88.1		5561	b	13.5	ab	127.6	b
Variety (V)	*******		*******		*******		*******	
1. LongReach Spitfire⌽	92.2	a	5043	d	14.3	a	121.9	bc
2. EGA Gregory⌽	81.8	b	5576	b	13.0	c	123.1	bc
3. Suntop⌽	86.1	b	5797	a	12.6	d	124.8	b
4. LongReach Lancer⌽	94.4	a	5595	b	13.7	b	129.8	a
5. LongReach Gauntlet⌽	96.0	a	5181	c	13.5	b	119.3	c
R x V	**n.s.**		**n.s.**		**n.s.**		**n.s.**	

Values with the same letter are not significantly different. ** po.01, ***po.001

Implications for growers

Despite the high protein, the crop was able to increase its yield where extra nitrogen was added to the upper layers of the profile. This could be attributed to the crop with access to nitrogen earlier in the season setting a higher seed number and therefore yield potential. When this season delivered a long, cool and wet grain fill period, it allowed the plants to develop a strong root system to extract their required nitrogen from deep within the profile and realise that yield.

The grain protein dilution effect (Figure 1) was consistent for all nitrogen rates applied in this trial. This equates to an average protein spread of 2% between the highest protein variety (LongReach Spitfire$^{\phi}$) and the lowest protein variety (Suntop$^{\phi}$) with a half-tonne per hectare yield penalty for the higher protein. Therefore, when growing the high yielding varieties such as Suntop$^{\phi}$ and EGA Gregory$^{\phi}$, it is important to ensure enough nitrogen is available to the crop to achieve high yields and proteins. However, if high grain protein is important then it may be beneficial to accept a slightly lower yield and grow a high protein achieving variety such as LongReach Spitfire$^{\phi}$.

In this trial there was no difference between the grain yield and protein of the 100% treatments applied either up front or split between pre-plant and in-crop applications. This allows a strategy of applying nitrogen fertiliser for an average yield potential, then applying additional nitrogen in the vegetative period of the crop, as in-crop rain increases the crop's yield potential.

The trial site experienced a wet spring

Acknowledgements

We would like to thank our co-operators who allow us to conduct these trials on their properties.

The Variety Specific Agronomy Packages program is co-funded by the Grains Research and Development Corporation, New South Wales Department of Primary Industries and Department of Agriculture and Fisheries. Seed supplied by Australian Grain Technologies, Advanta Seeds, Heritage Seeds and Seednet is appreciated.

Trial details

Location:	Goondiwindi
Crop:	Wheat
Soil type:	Brigalow scrub, Vertosol soil
In-crop rainfall:	280 mm
Fertiliser:	30 kg /ha of Granulock Z® Urea at various rates as per the treatment list

Wheat crop at head emergence and maturity

Wheat: impact of varying nitrogen treatments across different varieties and maturities—Allora

Duncan Weir
Department of Agriculture and Fisheries

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

Key findings

1. Targeting nitrogen rates will ensure that the crop will reach its yield and grain protein potential and limits losses through screenings.
2. Variety choice plays an important role in production outcomes.

Background

Recent trials conducted as part of the Variety Specific Agronomy Package (VSAP) has shown that wheat varieties responded differently to increased available nitrogen (N). This trial is one of a number of trials conducted throughout southern and central Queensland in 2106 to further explore the varietal interactions with different nitrogen levels and determine if these interactions are consistent across various Queensland conditions.

What was done

Five commercial wheat varieties and six treatments were tested using a randomised complete block design containing four replications. Each plot was 2 m x 10 m and consisted of seven rows planted 25 cm apart.

Varieties:

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

Nitrogen (N) treatments:

1. Nil (control)
2. 60% of yield potential
3. 80% of yield potential
4. 100% of yield potential
5. 100% of yield potential (50:50 split)
6. 150% of yield potential

Yield potential (YP) of the site was calculated at 5.5 t/ha using the APSIM model. Field N level prior to planting was 112 kg N/ha to 90 cm soil depth. N application rates were set based on the APSIM estimated yield potential (100% YP) and a target grain protein of 12% (Table 1).

Table 1. Applied nitrogen rates for each treatment

Treatment	Total N required (kg/ha)	Total fertiliser (kg/ha)	Urea (kg/ha)	Urea (g/plot)
Control	0	0	0	0
60% YP	125	12	26	48
80% YP	166	54	116	214
100% YP	208	95	207	380
100% YP Split	208	95	207	190 + 190
150% YP	312	199	433	795

Nitrogen treatments were applied 15 June 2016 three weeks prior to planting the wheat varieties on 12 July 2016.

Results

No significant response in flowering time or plant height was observed as a result of any of the nitrogen treatments.

Yield

There was a significant variety response with Suntop$^{\phi}$ producing significantly higher yields than all other varieties followed by LongReach Lancer$^{\phi}$. EGA Gregory$^{\phi}$ yielded the least (Table 2).

Table 2. Grain yield for all varieties at a nitrogen rate targeting 100% yield potential

Variety	Yield t/ha	
Suntop$^{\phi}$	6.205	a
LongReach Lancer$^{\phi}$	5.609	b
LongReach Spitfire$^{\phi}$	5.419	c
LongReach Gauntlet$^{\phi}$	5.242	cd
EGA Gregory$^{\phi}$	5.089	d

Letters indicate level of significance ($P < 0.05$)

There was a significant nitrogen treatment effect with T3 80% YP, T4 100% YP and T5 Split (100% YP) producing significantly higher yields than all other treatments (Figure 1). Yields increased with higher nitrogen rates until nitrogen rates reach 80% YP at which point yields remained the same or began to decline. There was no difference between applying all nitrogen prior to planting (T4 100% YP) and applying half prior to planting and the rest in-crop (T5 Split 100% YP).

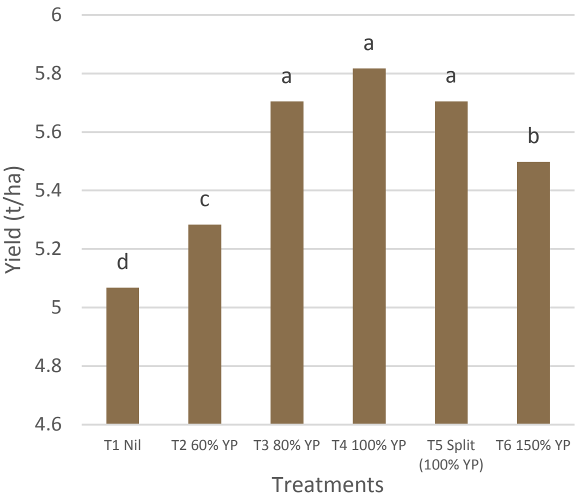

Figure 1. Treatment effect on yields. Letters indicated level of significance ($P < 0.05$)

Protein

For all varieties, grain protein levels were low for T1 Nil but increased with higher nitrogen rates.

There was a significant interaction effect between nitrogen treatments and variety on grain protein levels with the grain protein levels increasing significantly for all varieties with increased nitrogen (Figure 2). There was no significant yield increase after an average grain protein reaches 11% (Figures 1 and 2).

Screenings

There was no significant interaction effect between nitrogen and variety.

Results show that there was a significant response in screening percentage to treatments for all varieties. EGA Gregory$^{\phi}$ had a significantly higher screening percentage when compared all other varieties (Table 3) LongReach Lancer$^{\phi}$ and Suntop$^{\phi}$ had the lowest screening percentage. All varieties except EGA Gregory$^{\phi}$ were below the receival standard for premium grade wheat (5%).

There was also a significant treatment effect on screenings. T1 Nil, T2 60% YP and T3 80% YP had the lowest screenings, and weren't significantly different from each other (Figure 3). T4 100% YP and T5 Split (100% YP) were significantly higher. T6 150% YP had a significantly higher screening percentage than all other treatments, which was also the only treatment with greater than the allowable 5% screenings for premium grade wheat.

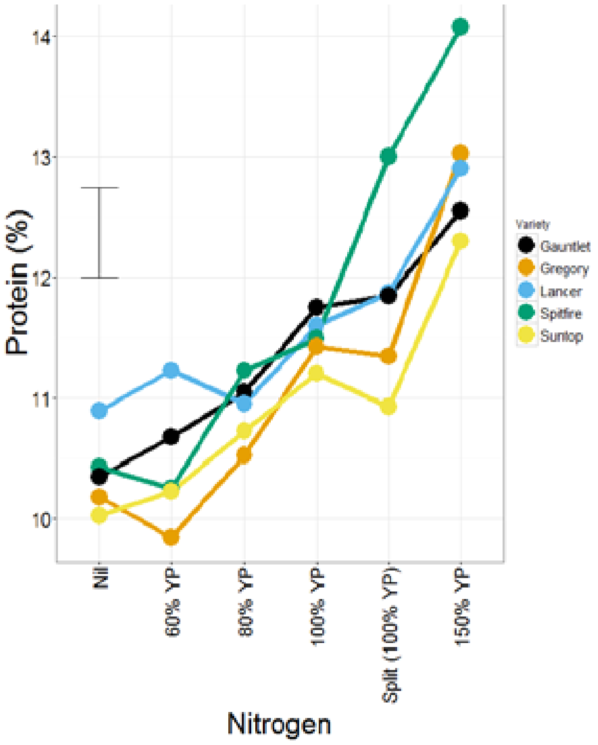

Figure 2. Interaction between treatments and variety on protein levels

Table 3. Screening percentages for varieties. (T4 100% YP)

Variety	Predicted screening %	
EGA Gregory$^{\phi}$	5.39	a
LongReach Gauntlet$^{\phi}$	4.21	b
LongReach Spitfire$^{\phi}$	3.94	bc
Suntop$^{\phi}$	3.56	cd
LongReach Lancer$^{\phi}$	3.2	d

Letters indicates significance ($P < 0.05$)

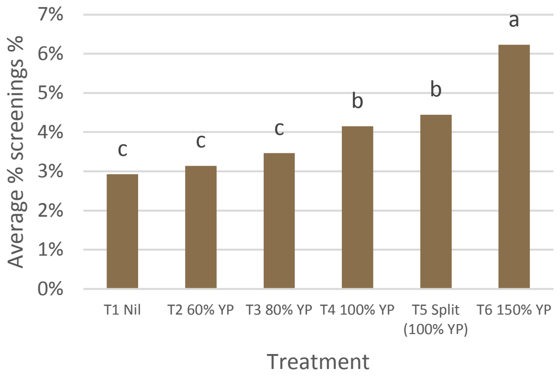

Figure 3. Screening percentages for treatments. Letters indicate level of significance P < 0.05%

Test weight

There was a significant varietal response in test weight to the treatments. LongReach Gauntlet$^{\phi}$ (test weight of 71.08 kg/hL) was the highest but not significantly different from Suntop$^{\phi}$ and Longreach Spitfire$^{\phi}$. EGA Gregory$^{\phi}$ was significantly lower (test weight of 69.21 kg/hL) than all other varieties.

There was also a significant treatment response in test weight with T5 150% YP having a significantly lower test weight (test weight predicted value of 68.08) than all other treatments. Although the T1 control treatment had the highest test weight it was not significantly different from T2 60% YP and T3 80% YP (Table 4). There was no significant nitrogen by variety effect.

Table 4. Test weights for treatments across varieties

Treatment	Predicted test weight (kg/hL)	
T1 Nil	71.53	a
T2 60% YP	71.21	ab
T3 80% YP	71.43	ab
T4 100% YP	70.53	b
T5 Split (100% YP)	69.53	c
T6 150% YP	68.08	d

Letters indicate level of significance ($P < 0.05$)

Implications for growers

The trial was conducted under very favourable weather conditions as can be seen in the above average yield results. This needs to be considered when assessing the results and applying them to commercial crop production. The trial does however support previous research and there are several important conclusions that can be drawn out.

Nitrogen levels play a critical role in achieving maximum yield and optimal grain quality. Targeting nitrogen levels which meet a 100% YP can ensure that the crop reaches its yield and grain protein potential and limits losses through screenings. Excessive nitrogen levels can reduce yield, increase screening and reduce test weights, while low nitrogen levels restrict yield and grain protein levels.

There are significant differences in performance between varieties and careful consideration should be taken when choosing a planting variety.

No significant response difference between T4 100% YP and T5 100% YP Split suggests there is no yield penalty for pre-fertilising for a long term average yield rather than 100% YP and applying addition nitrogen during the vegetative stage if seasonal conditions favour a higher yield.

Acknowledgements

We would like to acknowledge and thank our co-operators who allow us to conduct these trials on their properties.

The Variety Specific Agronomy Packages program is a continuation of co-funded research between New South Wales Department of Primary Industries and the Grains Research and Development Corporation. This work was contracted to the Department of Agriculture and Fisheries Regional Agronomy Network to complete six trials per year across the Queensland grain belt in 2015 and 2016.

Seed supplies from Australian Grain Technologies, Advanta Seeds, Heritage Seeds and Seednet for the supply of seed for the various trials.

Trial details

Location:	Allora
Crop:	Wheat
Soil type:	Black Vertosol
In-crop rainfall:	273 mm
Fertiliser:	50 kg of Granulock Z® at planting

Allora wheat trial in the late vegetative/early heading growth stage

Wheat: how does starting water and nitrogen impact across different varieties—Emerald

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[2]Queensland Alliance for Agriculture and Food Innovation

RESEARCH QUESTION: *Does available starting water play a significant role in varietal difference of yield and protein response to nitrogen application in Central Queensland?*

Key findings

1. Starting water does have a significant effect on both yield potential and water use efficiency of both varieties.
2. Suntop⌽ prefers a milder high N, high water scenario and will consistently outperform LongReach Spitfire⌽ in these conditions.
3. LongReach Spitfire⌽ will outperform Suntop⌽ in lower N and lower starting water situations, however limiting available N for given moisture will also limit yield potential of both varieties.

Background

Many locally adapted wheat varieties with great yield potential have been released, however breeding trials are generally assessed under ideal agronomic practice. Due to local soil and climatic limitations, and farmers' investment capacity and risk preferences often there is a gap between potential yield and realised yield.

This trial aims to assess how three starting nitrogen (N) scenarios perform against two starting plant available water (PAW) situations, and whether adjusting the agronomic management of the two starting water scenarios would have made a significant difference in yield and grain quality.

What was done?

The trial was planted on 19 May, 2016 on 25 cm row spacings with double disc openers and a covering press wheel behind. There was a considerable trash load from a previous summer crop in the field, and although it had been mulched, hair pinning was an issue.

Three nitrogen rates

1. Nil
2. 75 % of yield potential (YP)
3. 100 % of yield potential (YP)

Two varieties

1. LongReach Spitfire⌽
2. Suntop⌽

High residue loads at planting

Wheat emerging despite residue

Starting planting water

A sorghum crop was used to dry the soil profile, then irrigation was utilised to achieve two different starting waters for the trial to be planted into.

1. High starting moisture: 100 mm pre-irrigated (PAW 112 mm to 150 cm depth)
2. Low starting moisture: 50 mm pre-irrigated (PAW 26 mm to 150 cm depth)

An additional 75 mm was applied across both treatments, post planting to maximise germination and in an attempt to get starting water up to the 150 mm target used for the N calculations. The target N rates to achieve the calculated yield targets were applied via a combination of dissolved urea and granular urea immediately before planting (Table 1).

Table 1. Starting N and N (kg/ha) applied to achieve the calculated yield potentials required for the trial

Treatment	Predicted Yield	Total N required	Less current N	N applied at planting
	(t/ha)	(kg/ha)	(kg/ha)	(kg/ha)
Farmer Rate (Nil)	2.9	108	108	0
75 % YP	3.4	127	108	19
100 % YP	4.5	168	108	60

Observations taken in-crop included PAW at planting and harvest, emergence plant counts, flowering dates and plant height post grain fill. The trial was harvested on 11 October 2016 with yield and moisture recorded at time of harvest for all plots. Subsamples were collected from all plots, which were later used to perform grain quality assessments including protein, screenings (%), and test weight. Harvest water and N was also measured on the same day as harvest.

Results

There were no observed differences in initial plant counts for both the high water and low water treatments. An average of 638,000 plants/ha established across all three N treatments in the high water, and slightly higher at 689,000 plants/ha for the low water treatment.

There was a difference in established plants between varieties for the high water treatment, with LongReach Spitfire$^{\phi}$'s establishment being significantly higher ($P<0.001$) with an average of 728,333 plants established per hectare, as opposed to Suntop$^{\phi}$ with 549,167 plants established. The difference in established populations for the low water treatment was not significant, because of the higher variability of plants established between replications. These population differences have been consistent across multiple trials in 2015 and 2016, indicating that LongReach Spitfire$^{\phi}$ may inherently have more vigour than Suntop$^{\phi}$.

LongReach Spitfire$^{\phi}$ and Suntop$^{\phi}$ are recognised as having similar maturities and this held true with flowering observations. There were no significant differences ($p=0.05$) observed between flowering dates of the two varieties, nor was there a significant difference observed between N treatments, averaging around 78 days after planting.

The Suntop$^{\phi}$ was a slightly taller plant at grain fill (Figure 1), and with plenty of N available to it in the 100% YP treatments, seemed to have a greater capacity to maximise yield, compared to the shorter LongReach Spitfire$^{\phi}$. Changing starting PAW or N rates has not had an impact on plant height in this trial.

Harvested yields in the high water treatment remained consistent with other trials conducted in Emerald this season. With higher starting

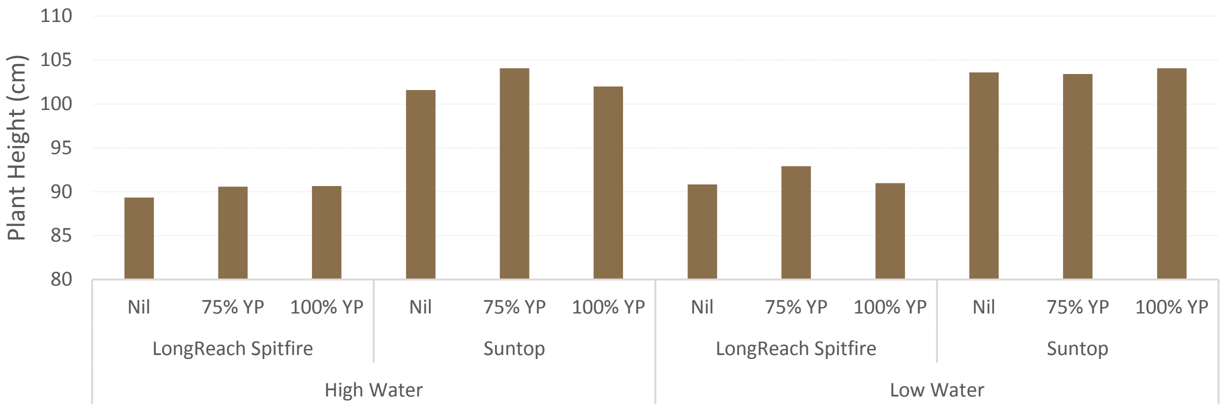


Figure 1. Average plant height of the trial varieties post grain fill

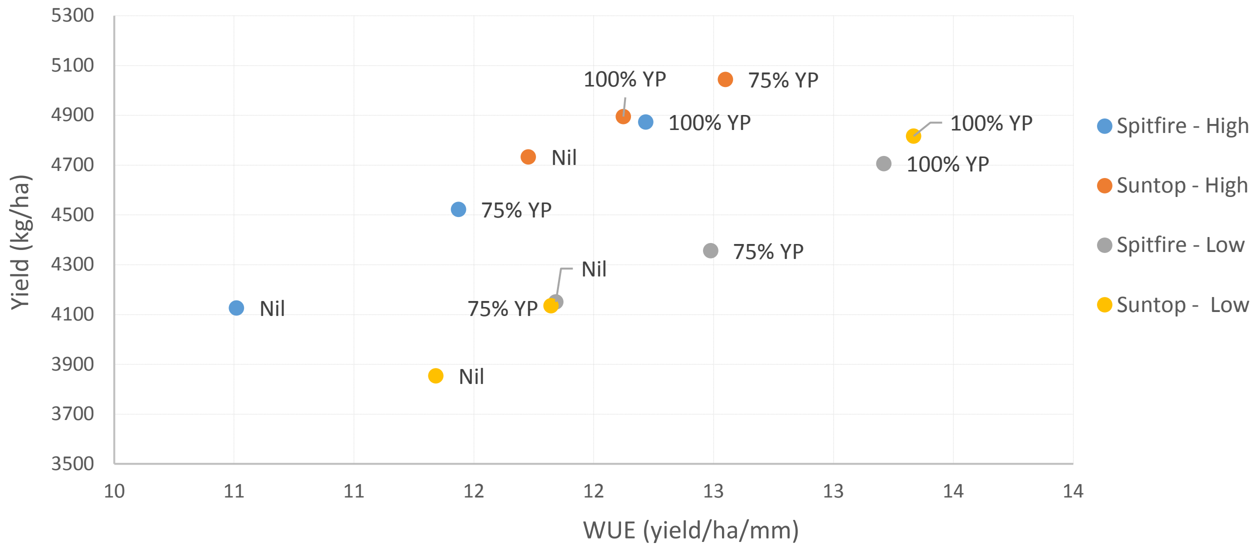


Figure 2. Grain yield and water use efficiency of variety x PAW (the three points are the increasing N rates)

PAW, Suntopᶲ yielded significantly higher (P>0.001) than LongReach Spitfireᶲ averaged across all N treatments. As the N rate increased the yield difference narrowed between the two varieties, with the 100% yield potential treatments not having any significant yield difference. There was also a significant difference (P<0.05) between the nil N treatment and the two N treatments (75% and 100% yield potential), with yield increasing as N rates increased (Figure 2).

With lower starting PAW, there was no significant difference between the average yields of varieties, 300 kg/ha less than the equivalent high PAW treatments. There was a significant trend for increasing yield for higher N rates, with the best yields achieved in the 100% YP treatments (2).

Grain qualities were excellent for both water treatments, with screenings ranging from 2% to 3.3% and test weights all over 81 kg/hL. Proteins were significantly different (P<0.001) between the varieties, with LongReach Spitfireᶲ averaging 1.5% higher protein than Suntopᶲ across all the treatments. The trend was also very strong indicating that as N increases, so too does protein. This difference was significant in the high water treatment, indicating 100% YP was significantly higher than the other two treatments. In the low water treatments this trend was not significant (P<0.05) with 100% YP having 12.8% protein.

For this trial, water use efficiency (WUE) did improve in the low starting water scenario, compared to the high water scenario (Figure 2). Similarly, increasing N rates also improved WUE with the 100% YP application producing the highest yield and the most efficient use of water. Despite the improvement in WUE, the low starting water was not able to match the average yields of the higher starting water scenario.

Interestingly we saw high variability in yield and WUE in the low water scenario, between treatments for Suntopᶲ when compared to LongReach Spitfireᶲ, however this was completely reversed in the high water scenario, where Suntopᶲ showed considerably less variability than LongReach Spitfireᶲ.

Implications for growers

Suntopᶲ and LongReach Spitfireᶲ have been recognised for some time for displaying very different characteristics for accumulating yield and protein. These differences have been consistent across the northern region.

This was particularly so in the higher starting water scenario where Suntopᶲ consistently out-yielded LongReach Spitfireᶲ however, WUE was reduced. For the more typical in-crop dryland scenario however, LongReach Spitfireᶲ in a low N (nil) or limited N (75% YP) supply scenario with limited available water, particularly at planting, yielded better than Suntopᶲ.

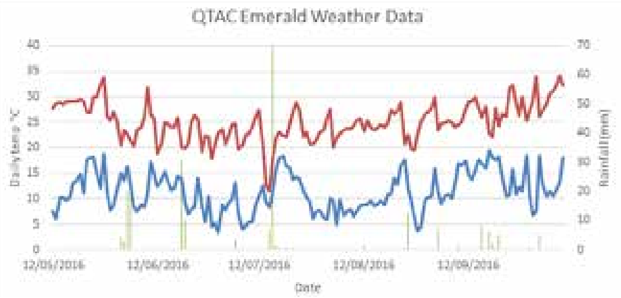


Figure 3. Trial site daily maximum and minimum temperatures and rainfall

Acknowledgements

The Department of Agriculture and Fisheries, Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI) and the Grains Research and Development Corporation are co-funding the research project, UQ00074 ‘High yielding cereal agronomy in the northern grains region’. QAAFI is the lead researcher for the project.

Trial details

Location:	Field 5, Block 12 at the Queensland Agricultural Training College, Emerald
Crop:	Wheat
Soil type:	Grey cracking Vertosol with a water holding capacity in excess of 230 mm
In-crop rainfall:	The trial had starting plant available water of 63 or 16 mm down to 90 cm at the time of planting. There was a total of 228 mm of in-crop rainfall received (Figure 3). An additional 75 mm of water was applied on 27 May and 50 mm applied on 16 August as overhead sprinkler irrigation
Fertiliser:	Starting nitrogen on the site was 108 kg/ha, Addition to the N treatments applied as described in the ‘What was done’ section of this report. 30 kg/ha of Granulock Z® was also applied with the seed at planting

Spitfire$^{\phi}$ (left) and Suntop$^{\phi}$ (right) starting to turn

View from the trial planter

Pulse agronomy research

The pulse agronomy research across Queensland has been spearheaded by the Grains Research and Development Corporation–funded project UQ00067 (Queensland Pulse Agronomy Initiative) lead by QAAFI (UQ). Over the past three years there has been a series of trials in both Southern Queensland (SQ) and Central Queensland (CQ) focused on the interaction between genetics, environment and management (GxExM) for these crops. This approach has a strong basis on plant physiology and hence a number of the outcomes are measured not only by grain yield but also by dry matter production, harvest index, leaf area index and water use efficiency.

Trials conducted so far have incorporated spatial variability (populations and row spacing), weather impacts (time of sowing) and water use efficiency (irrigated and dryland) across a number of commercial varieties (genetics). These trials not only gave information that can be directly related to best practice agronomic recommendations but can also help define the plants key physiological characteristics which in turn can be used to inform future areas of productivity improvement.

The 2016 trials have basically confirmed and added to a number of key findings from previous trial data. The 2016 mungbean trials in CQ showed a yield response to narrow rows (25 cm and 50 cm) but only when yield expectations were above 1.5 t/ha. Plant population trials demonstrated no yield response to populations between 15 plants/m^2 to 35 plants/m^2 but a significant reduction in yield when populations were below 15 plants/m^2 in both mungbeans and chickpeas.

Time of sowing trials showed mungbeans are not always vegetatively determinate at flowering depending on soil water conditions. Mungbeans also demonstrated better water use efficiency when in-crop water (irrigation or rainfall) was available around flowering regardless of stored soil moisture conditions. The 2016 chickpea time of sowing trials demonstrated a significant yield penalty (<1 t/ha) to late sowing (August) however some of his yield penalty could be reduced (60%) by improved soil moisture conditions (rainfall or irrigation) in late spring.

Generally genetics had little influence on grain yield performance of both chickpea and mungbean across the trials in 2016. However genetics do play a role in qualitative measures such as seed size and disease resistance. This has been a similar story across a number of seasons.

Future trials will focus on the manipulation of harvest index in chickpeas and whether yield improvements can be gained by reducing early dry matter production particularly in early planting windows. Further understanding of the relationship between water use efficiency and weather conditions particular in mungbean production will occur in 2017.

Mungbean: effect of time of sowing and row spacing on yield with and without irrigation—Warwick

Rod O'Connor, Kerry McKenzie and Jayne Gentry
Department of Agriculture and Fisheries

Research Question: *Does time of sowing and row spacing have an effect on dry matter production and yield with or without irrigation on mungbeans at Warwick?*

Key findings

1. The narrower row spacings (25 and 50 cm) produced greater yields.
2. The difference in yield from 100 cm to 25 cm is less at lower yield potentials.
3. The January planting date produced the greatest yield with over 2.5 t/ha when irrigated.

Background

Mungbeans play a significant role in Queensland and New South Wales, with increasing areas planted under favourable seasonal conditions. This, alongside with the increasing economic benefits of pulse crops, provides a great opportunity to increase planting area of pulse crops and their profitability with greater understanding and improved management. The main objective of the Queensland Pulse Agronomy Initiative (UQ00067) is to better understand the ideal agronomic management and growing conditions and to promote opportunities for mungbeans and other pulse crops to be included in the farming systems of the northern grains region.

This project was interested in determining the impact different times of sowing (TOS) had over various plant populations and row spacings, and if differing yield potential (via the use of irrigation) impacted on these results.

What was done

The trial was run at the Queensland Government Hermitage Research Station (HRS) situated at Warwick in southern Queensland. The trial was designed to include plus and minus irrigation runs; three planting dates TOS1 (8 December 2015), TOS2 (14 January 2016) and TOS3 (11 February 2016); three row spacings (25, 50 and 100 cm) and four plant populations (10, 20, 30 and 40 plants/m^2). This was replicated three times. Jade-AUP was planted across the whole trial and starter fertiliser was applied at 50 kg/ha.

Tape was laid down to administer irrigations as required. However, TOS1 received 246 mm in-crop rainfall with regular falls hence there was no perceived requirement for irrigation. Irrigation of 195 mm in two applications was applied to the irrigated treatment in TOS2 (with 170 mm in-crop rainfall) and TOS3 had 150 mm of irrigation in two applications (with 98 mm in-crop rain).

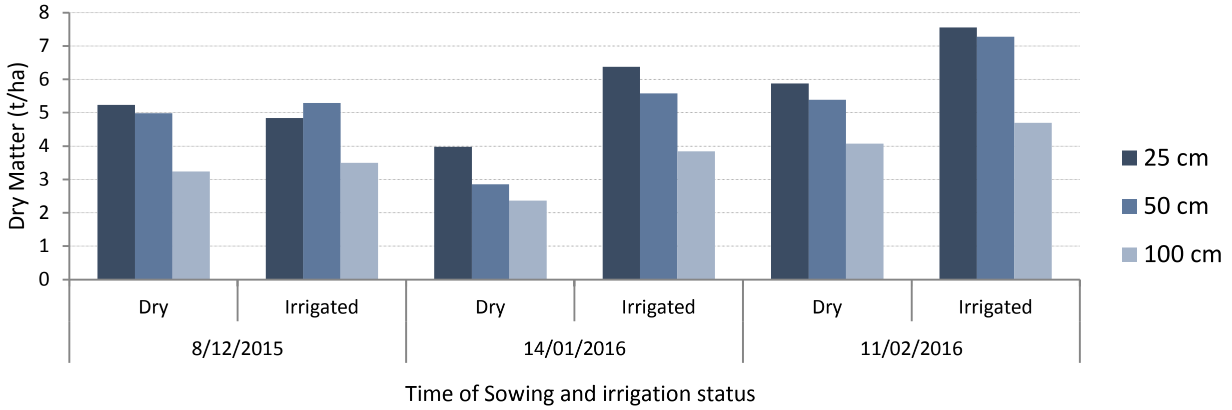


Figure 1. Dry matter production dryland and irrigated across three TOS and three row spacings; LSD = 844 kg/ha

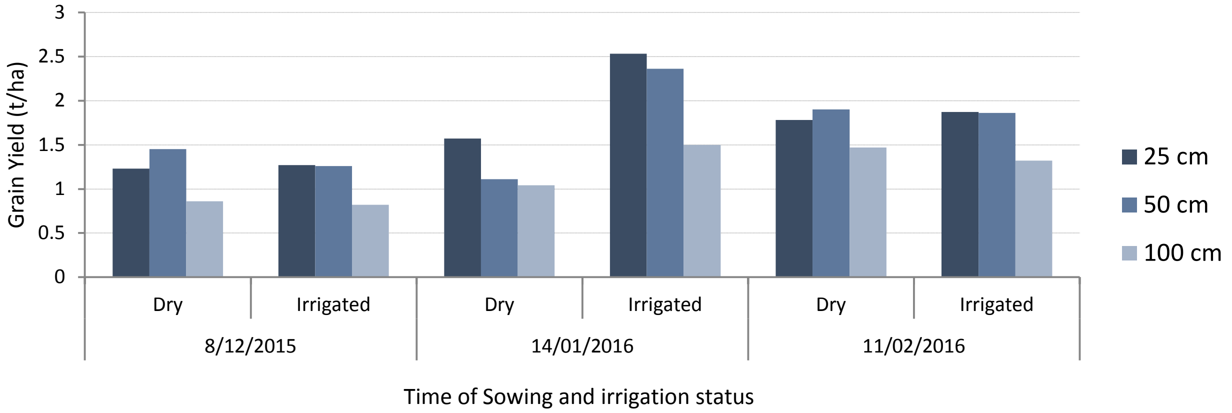


Figure 2. Grain yield dryland or irrigated across three TOS and three row spacings; LSD = 349 kg/ha

Once plants reached maturity, a 1 m cut out of the plots was taken to assess total dry matter production (TDM). Plots were machine harvested to measure grain yield. For both dry matter and grain yield the plot edge was avoided, i.e. only five of the seven rows for the 25 cm treatment, two rows for the 50 cm and both 1 m rows were harvested.

Results

No significant differences were observed for the four plant populations. Dry matter was highest in the narrower row spacings with 25 and 50 cm having between 1.1 and 2.3 t/ha more dry matter production across all three TOS compared to the 100 cm treatment (Figure 1).

Grain yield was maximised in this trial in TOS2 in 25 cm rows when irrigated (Figure 2). TOS2 had the largest difference between irrigated and dryland treatments for grain yield with an almost 0.9 t/ha increase when averaged across the three row spacings. The greatest difference in yield was also seen in the TOS2 between 1 m rows and 25 cm rows, with a 1 t/ha increase in the irrigated and 0.5 t/ha in the dryland treatments.

The grain yield for TOS3 did not follow similar patterns with yields almost the same in each row spacing whether it was irrigated or dryland (Figure 2).

Previous trial results have shown a direct correlation between dry matter production and grain yield at a harvest index (HI) of 0.3. This trial had an overall HI of 0.32 but with large variations across the times of sowing and treatments. TOS2 was well above this HI with an average of 0.41 over all treatments, however the irrigated TOS3 HI was only 0.27 (averaged across the three row spacings).

A key environmental difference between sowing dates is day temperature. Mungbeans are a vegetative determinant plant (i.e. once they have grown their potential biomass there is limited increase after this point) and is a reproductive indeterminate plant with the beginning of flowering approximately four weeks after

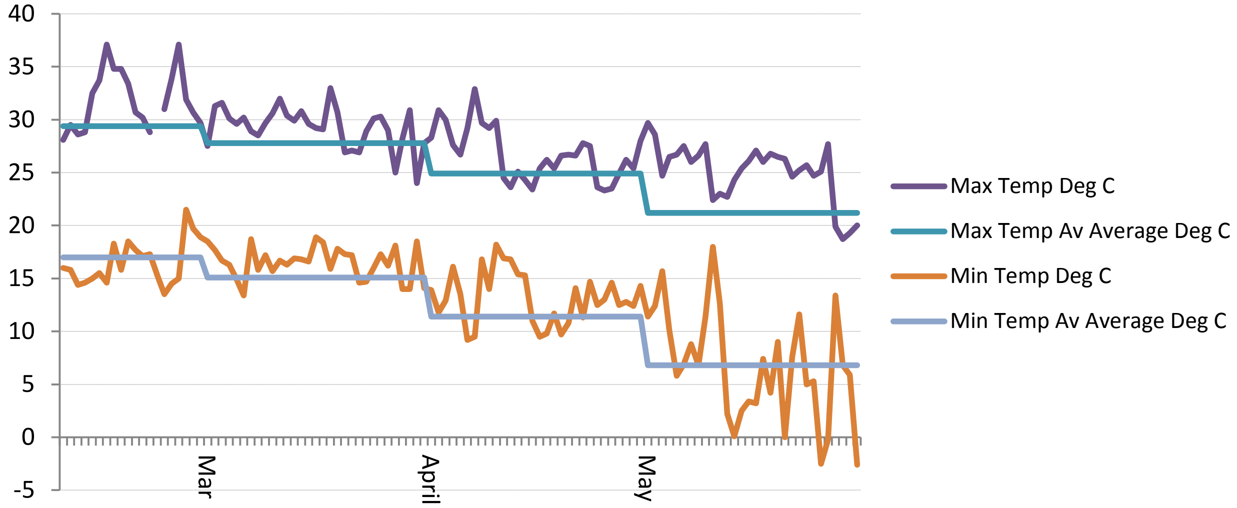


Figure 3. Temperature for TOS3

planting, continuing to flower if conditions are suitable. Mungbean is sensitive to temperature particularly during flowering, with hot conditions resulting in flower abortion and temperatures below 15°C slowing growth and seed set. The average maximum temperatures during flowering time for TOS1 was around 30°C, for TOS2 the temperature began around 30°C dropping to 25°C and for TOS3 the temperature at flowering began around 27°C and dropped to 22°C (Figure 3). For TOS3 the minimum temperatures at the start of flowering and until maturity were 15°C and below which may have limited yield potential, particularly for the irrigated treatment.

It is suspected that the lower temperatures for TOS3, particularly after flowering had commenced, limited yield. Temperatures and water availability were sufficient to drive differences in dry matter production between the irrigated and dryland treatments prior to flower initiation. Temperatures then dropped and conversion from biomass to grain yield did not allow for expected HI.

Implications for growers

Mungbeans planted on narrower row spacings (25 and 50 cm) produced greater yield across all treatments. Mungbeans are sensitive to climatic conditions in particular waterlogging and day temperature during the flowering period and planting decisions should be based on expected temperatures at the critical flowering period. Where irrigation is available, yield gains with two waterings can be achieved. Even though there were no differences between plant populations, it is still recommended to observe current best management plant populations of 25 plants/m^2 for dryland and 30 to 40 plants/m^2 under irrigation.

Acknowledgements

This project is funded by the Grains Research and Development Corporation, the Queensland Alliance for Agriculture and Food Innovation and the Department of Agriculture and Fisheries.

Trial details

Location: Hermitage Research Station
Crop: Mungbean (Jade-AU$^{⒟}$)
Soil type: Brown Vertosol
In-crop rainfall: TOS1 = 246 mm
TOS2 = 194 mm
TOS3 = 175 mm

Fertiliser and pests were managed on an as-required basis with starter application at 50 kg/ha

50 cm row spacing on mungbeans at HRS early stage with 25 cm row spacing behind

50 cm row spacing on mungbeans at HRS late stage with 100 cm row spacing behind

Close up mungbeans at HRS during pod fill

Mungbean: yield response to row spacing and plant population under high yielding conditions—Biloela

Doug Sands
Department of Agriculture and Fisheries

RESEARCH QUESTION: *Does the performance of commercial mungbean varieties change under different row spacings and populations in Central Queensland under high yielding conditions?*

Key findings

1. There was a significant increase in grain yield with narrow row spacings.
2. There was a significant grain yield penalty under low plant populations.
3. The higher the mungbean biomass production the higher the grain yield.

Background

Over the last two years (2014/15 and 2015/16 summer seasons), a number of dryland row spacing and population trials were conducted throughout Central Queensland (CQ). This was done to test whether changing the spatial positioning of plants could improve grain yield via the more efficient interception of light; and better access to stored soil water and nutrients. Most of these trials produced low to average yields, with the data sets indicating little consistent yield difference between any of the row spacing and plant population treatments. All of these trials produced yields less than 1.2 t/ha.

The project team were interested in assessing the impact of row spacing and plant population on the full range of mungbeans yields that have been historically achieved in the CQ region to date. To complete this assessment, there was a requirement to collect data from mungbean trials that yielded greater than 1.2 t/ha. In the 2016/17 season, high fertility sites were targeted where irrigation could be applied throughout the season to maximise yield potential.

What was done

An irrigation site was identified near Biloela, on the Kroombit Creek floodplain, which historically yielded over 2 t/ha of mungbean. Grower experience suggested that fertility of the site was adequate, except for sulfur (S), which was marginal. The paddock was fertilised with 70 kg/ha of Gran-Am® following the harvest of the 2015 chickpea crop; with a full disturbance cultivation. A soil test taken at planting on 11 February (Trial details); indicates that the site had adequate fertility with over 50 kg/ha of nitrogen (N), 100 kg/ha of phosphorus (P) and 15 kg/ha of sulfur (S) available in the top 30 cm of the profile. Heavy rainfall over January 2016 filled the soil profile (approximately 215 mm), hence additional pre-plant irrigation was not required. The trial was planted on 10 February.

Three commercial varieties were planted (Jade-AU$^{\Phi}$, Crystal$^{\Phi}$ and Satin II$^{\Phi}$) on four row spacings (25, 50, 75 and 100 cm) over four plant populations (10, 20, 30, 40 plants/m^2). There were three replicates, with a plot size of 4 m x 15 m. An equivalent to Starter Z® was applied with the seed at 30 kg/ha.

Established plant populations were counted and flowering notes were recorded during the season. There were establishment issues across the trial. As a result the 10 plants/m^2 plots were so variable that they were not included in the yield analysis. The other plots were more consistent but average plant establishments were lower than targeted densities (Figure 1).

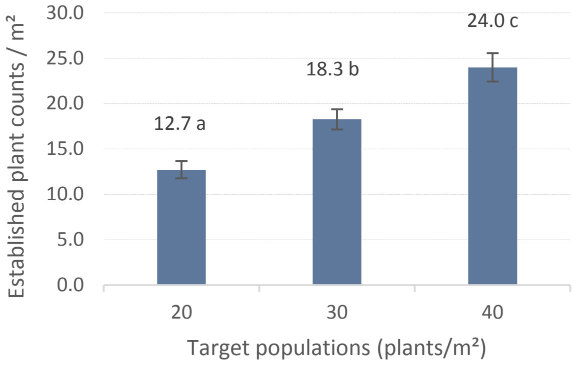


Figure 1. Average plant establishment in target populations (l.s.d (5%) = 1.8)

Total dry matter cuts were conducted when crop reached maturity (90% black pod). Two harvest samples we taken from each plot. Starting soil moisture and nutrient status at planting; and soil moisture at harvest was recorded. The crop received 45 mm in-crop rainfall and one in-crop irrigation of 50 mm, three weeks after emergence.

Results

There was a significant reduction in both dry matter and grain yields with populations averaging 13 plants/m². However there was no significant difference between 18 and 24 plants/m² at a yield of 1.8 to 1.9 t/ha (Figure 2). This would indicate that there is a lower limit to population targets when potential yields are above 1.5 t/ha. This population data is limited by the fact that there were no populations above 25 plants/m² so it cannot be proved that higher populations (>30 plants/m²) would have achieved similar or better yields than 25 plants/m². It is clear that the mungbean plant can compensate for differences in populations but there is a limit to this when populations are approaching 10 plants/m² and potentials yields are above 1.5 t/ha.

The row spacing results (Figure 3) indicate a significant difference between narrow and wide row spacings. There was no significant difference between 25 and 50 cm nor between 75 and 100 cm rows. However there was a highly significant difference between 25 and 50 cm rows in comparison to 75 and 100 cm rows. This indicates that a narrow row configuration (25 to 50 cm) will provide a yield benefit (24% or 380 kg/ha) in both dry matter and grain yield in situations where there is higher yield potential (>1.5 t/ha).

Comparison of plant establishment: 10 plants/m² on the left and 30 plants/m² on the right

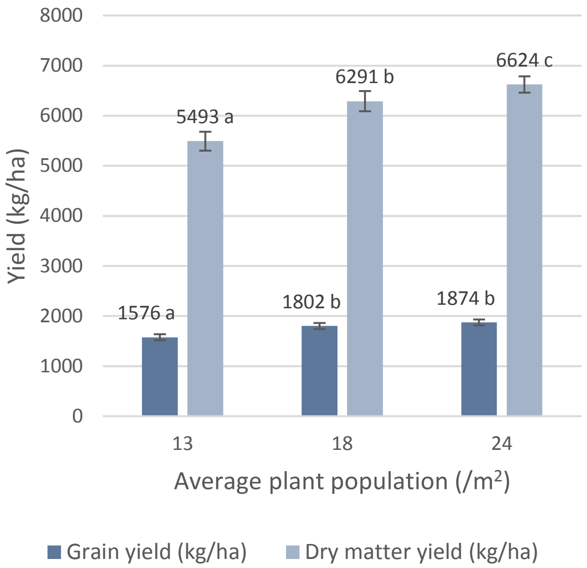


Figure 2. Comparison of grain and dry matter yields across populations. LSD grain yield 92.2, dry matter 342

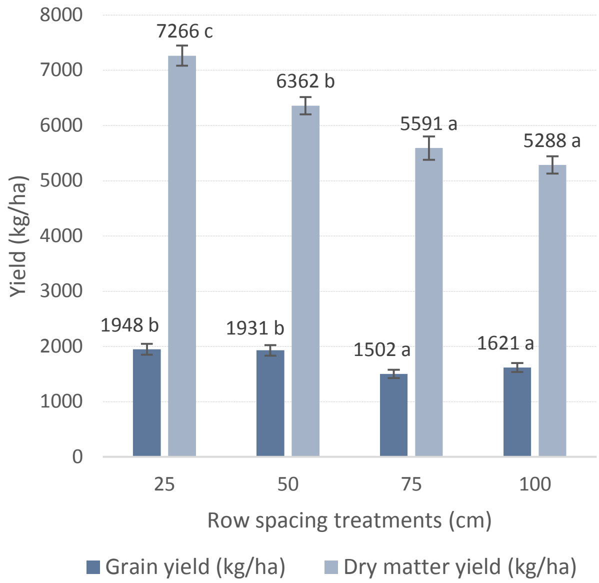


Figure 3. Comparison of grain and dry matter yields across row spacings. LSD grain yield 135.1, dry matter 373.7

Note: Values with like letters are not significantly different.

There was no significant difference between varieties even though there was a 200 kg/ha difference between Crystal$^{\phi}$ and Jade-AU$^{\phi}$ (Figure 4). The dry matter comparison between varieties was very even with less than 100 kg/ha difference between all three varieties although there was some variability within these averages which is why the Least Significant Difference (LSD) is so large.

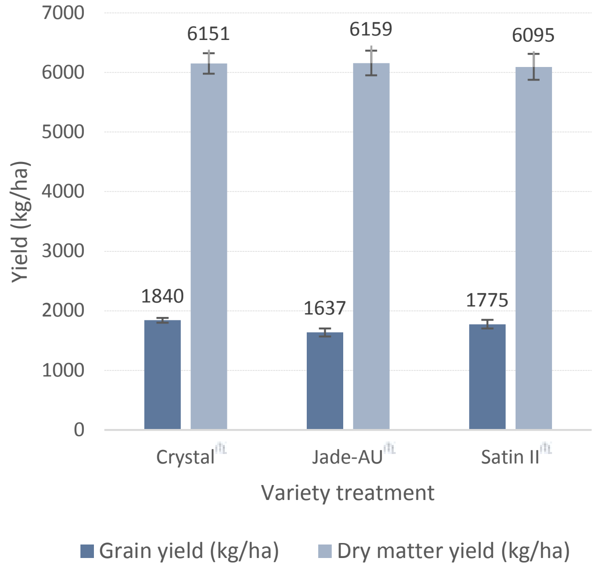


Figure 4. Comparison of dry matter and grain yield across varieties. **LSD=grain 364.8, dry matter 806.2 (n.s)**

There was no significant difference for harvest index (Figure 5) across all three variables (variety, population, row spacing), despite there being some significant differences in grain yield. Harvest index is a measure of the total grain yield divided by the total dry matter production. It is an excellent indicator of the relationship between the vegetative mass of the crop and the amount of grain produced. The data in Figure 5 would indicate a reasonably consistent ratio between dry matter production and grain yield, with the variation fluctuating between 0.26 and 0.32. Therefore as the vegetative mass of the crop increases so does the grain yield. This data supports the theory that dry matter production is strongly related to grain yield in mungbeans, particularly in high yielding conditions.

Implications for growers

Narrow row spacing and moderate to high plant populations have a positive impact on grain yield in high yield potential conditions. Previous trials showed no impact on yield from row spacing and population changes, however these data sets were generated in low yielding situations (0.5 t/ha to 1.2 t/ha). However, this trial yielded between 1.5 t/ha and 2 t/ha and demonstrated a significant improvement in grain yield due to narrow rows (25 to 50 cm) and a significant loss of yield at low populations (<13 plants/m²).

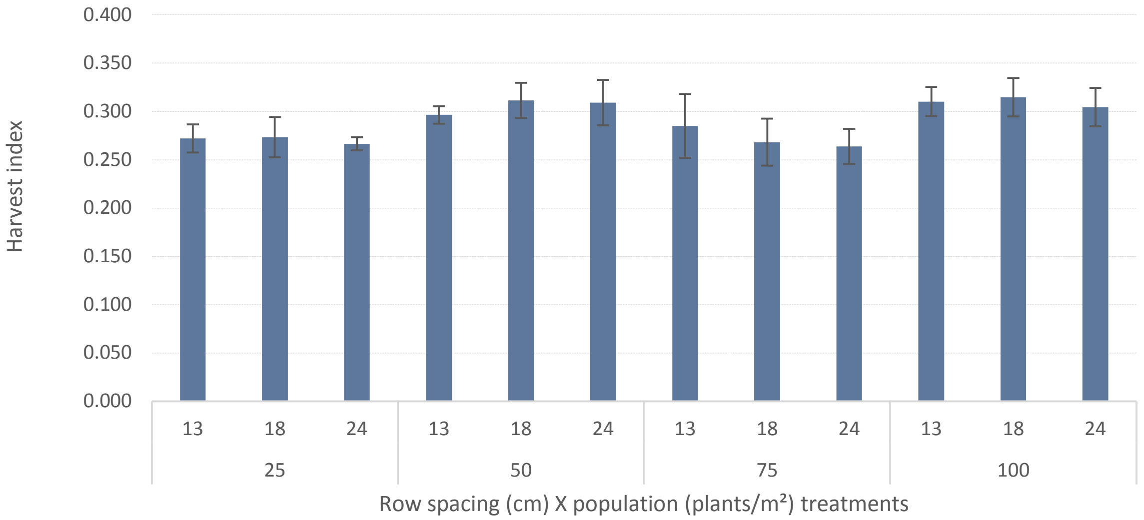


Figure 5. Comparison of harvest index between row spacing and population treatments
LSD= row spacing 0.0379, population 0.0209 (n.s)

Growers with potential to grow high yielding mungbeans should consider the potential benefit of using narrow rows (25-50 cm) over the more traditional wider row setups (75-100cm); and this benefit could be as much as 25% or an extra 400 kg/ha of grain. At the other end of the scale, higher yields can be discounted by as much as 15% or 250 kg/ha of grain, if plant populations are too low (‹150,000 plants/ha).

Comparison of varieties: Jade-AU$^{\phi}$ on the left and Crystal$^{\phi}$ on the right

Comparison of row spacing: 100 cm rows on the left and 25 cm rows on the right

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 (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:	Biloela
Crop:	Mungbeans
Soil type:	Brown Dermosol (Alluvial loam)
In-crop rainfall:	45mm
Irrigation:	50 mm
Fertiliser:	Gran-Am® as pre-plant application 70 kg/ha
	Starter Z® equivalent at planting 30 kg/ha

Selected soil test characteristics measured at planting:

Depth Increments	Nitrate Nitrogen	Phosphorus Colwell	Sulfur	Exc. Potassium	Conductivity	DTPA Zinc	pH Level (H2O)	N available
	mg/Kg	mg/Kg	mg/Kg	meq/100g	dS/m	mg/Kg	pH	kg/ha
0-10	15	41	4.3	0.98	0.036	1.4	7.3	19
10-30	12	19	3.3	0.6	0.033	0.84	7.3	33
30-60	13	12	3.5	0.41	0.051	0.53	7.4	59
60-90	7	n/a	3.9	n/a	0.056	n/a	8.3	32
90-120	4	n/a	3.4	n/a	0.051	n/a	8.5	18

Mungbean: impacts of time of sowing on row spacing and population treatments in spring planted crops—Emerald

Doug Sands
Department of Agriculture and Fisheries

***Research Question:** Are the effects of row spacing and population changed by different times of sowing in spring planted mungbeans?*

Key findings

1. Narrow rows (25 cm) provided an improvement (10-20%) in grain yield and dry matter production.
2. Low populations (10 plants/m^2) provided an improvement (15-18%) in grain yield but no difference in dry matter production—in contrast to past research.
3. There was no significant interaction between time of sowing and row spacing or population.
4. There was a reduction in grain yield from the October time of sowing.

Background

Over the last two years the Pulse Agronomy Initiative (UQ00063) have been conducting experiments to quantify the impact of different row spacing and populations on dryland mungbean yields. Essentially these experiments have found very little response to population changes (10 to 40 plants/m^2) and row spacing changes (25 cm to 100 cm rows). Most of this data has been collected across low yielding dryland sites (0.5 to 1.2 t/ha). The main gap in this information is whether the non-response is the same in higher yielding situations (>1.5 t/ha).

Information is also required determining the effect time of sowing (TOS) has on the physiology of mungbean in Central Queensland (CQ). Mungbeans have a wide planting window in CQ, from September through to March. This wide planting window means the plant can experience very different climatic conditions between spring (September, October, November) and summer (December, January, February). It is essential to quantify the impacts of weather on the physiology of the plant and how row spacing and plant population impact upon this; not only to optimise yield but also to manage risk in relation to the reliability of that yield.

What was done?

A trial was conducted at the research facility based at the Emerald Agricultural College. Mungbeans were planted at three sowing dates (September, October, November) in a randomised block design with each TOS split into four row spacings (25, 50, 75 and 100 cm) and each row spacing block was further split into four populations (10, 20, 30 and 40 plants/m^2). One variety was used across the trial (Jade-AU$^{\text{Ⓓ}}$) and all treatments were replicated three times. Each plot was 4 m wide by 16 m long and Supreme Z® was applied with the seed at 30 kg/ha.

Due to ongoing dry conditions the trial block was pre-irrigated twice before the first planting ensuring there were good levels of starting plant available water (120 mm) to a depth of 90 cm. The second and third plantings had top up irrigations before planting to ensure similar starting soil moisture conditions.

Plant establishment counts indicated all populations were close to target populations (Figure 1). Soil cores were taken just after planting to establish starting moisture levels and nutritional status (see Trial details).

Dry matter cuts were taken at the start of flowering and at full maturity. Light interception readings were taken at the first flower stage along with days to flower notes for each plot.

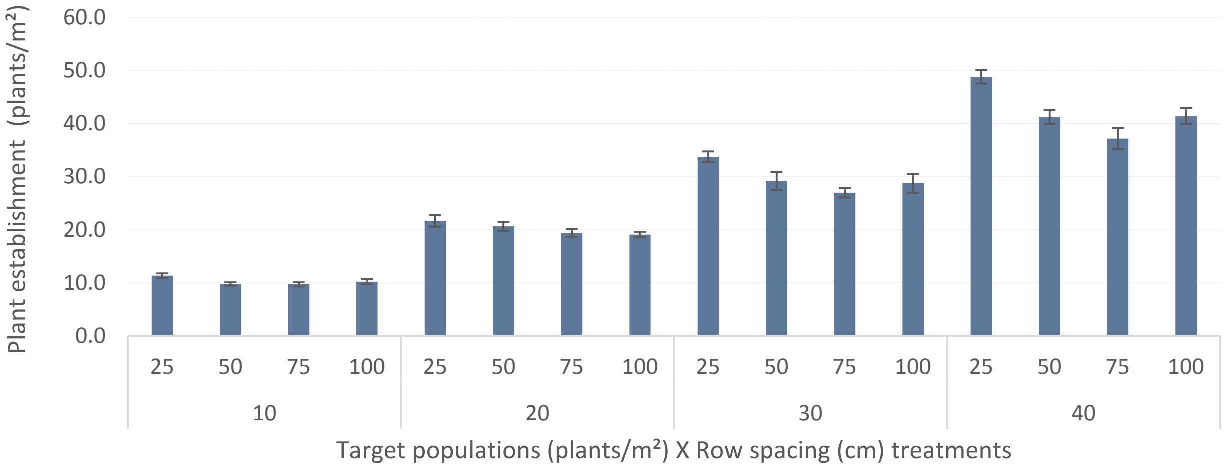


Figure 1. Plant establishment counts versus target population treatments

Plant counts in October time of sowing, September planting on left

Maturity dry matter cuts were split into pods and vegetative samples and dried separately before all the pods were thrashed out and weighed for a hand harvest yield assessment. Machine harvest yields were also measured although the third planting received excessive rain after desiccation and most of the seed sprouted in the pods before it was dry enough to harvest. Consequently no machine harvest data was recorded for the November sowing time.

Weather data was recorded throughout the trial from an Oz Forecast weather station positioned close to the trial site. This weather station takes readings every 15 minutes and records temperature, humidity, radiation, rainfall and evaporation.

Results

There are two main parts to this trial; one is the performance of the row spacing and population treatments and their interactions. The second is the impact of the time of sowing on the overall performance of the crop as well as any interactions with row spacing and population treatments.

Even though the trial was targeting grain yield over 1.5 t/ha, all treatments yielded less than this level. However, there were still some small significant differences in both population and row spacing (Table 1). The narrow rows (25 cm) produced significantly more yield than the wider rows (75 and 100 cm), with the 50 cm treatment

Table 1. Comparison of row spacing and population treatments averaged across TOS—grain yield, dry matter production and harvest index

Variable	Treatment	Hand harvest mean grain yield (kg/ha)		Total dry matter means at maturity (kg/ha)		Harvest Index	
Row spacing (cm)	25	1467	b	4241	b	0.35	ns
	50	1353	ab	3818	a	0.36	ns
	75	1319	a	3656	a	0.362	ns
	100	1212	a	3496	a	0.356	ns
Population (plants/m²)	10	1466	c	3989	ns	0.372	c
	20	1355	b	3720	ns	0.365	bc
	30	1294	ab	3828	ns	0.347	ab
	40	1237	a	3674	ns	0.344	a

lsd = least significant difference (P=0.05). Means with the same letter are not significantly different (lsd: Grain Yield = row spacing 143.3, population 110.2; Dry matter = row spacing 348.1; Harvest index = population 0.0187). ns = not significant.

yields falling in-between. Dry matter production followed the same pattern with the 25 cm rows producing significantly more dry matter (21% or 745 kg/ha) in comparison to the 100 cm rows.

The population results were unexpected with the lowest population (10 plants/m²) producing significantly the highest yield and the highest population (40 plant/m²) producing the lowest yield. This was a significant yield difference of over 18% (229 kg/ha) between the two extremes of the population treatments and 10-20% (150–250 kg/ha) improvement in yield for 25 cm over wide rows (75 cm, 100 cm).

Harvest index was largely uniform across all treatments although there was a small significant improvement in the 10 plants/m² population in comparison to the 40 plants/m² in line with the grain yield results.

Across all populations and row spacing there was no significant interaction between the various combinations of the two nor was there any significant interactions with time of sowing. This data reinforces the concept that narrow rows can improve yield and dry matter production, even though yields were moderate (1-1.5 t/ha). However, this data shows the lowest plant population producing the highest yield; the complete opposite of results produced in higher yielding trials. There is no real explanation for this result.

Table 2. Comparison of planting windows performance on grain yield, dry matter production and harvest index

Time of sowing	Hand harvest mean grain yield (kg/ha)		Total dry matter means at maturity (kg/ha)		Harvest Index	
Sep	1425	ns	4579	ns	0.313	a
Oct	1071	ns	3249	ns	0.331	a
Nov	1517	ns	3580	ns	0.426	b

#least significant difference (P=0.5). Means with the same letters are not significantly different (lsd: harvest index = 0.0359). ns = not significant

Although the differences in mean grain yield between planting dates is over 30% with the November plant being highest yielding and the October the lowest, there is no statistical difference between planting dates. This is partially explained by large standard error existing between replicates, potentially due to the positioning of overhead irrigation.

Dry matter production produced no significant differences as well but did not follow the same pattern as grain yield. The September sowing window produced the most dry matter by 1 t/ha or more. The November sowing window produced a significantly higher harvest index of 0.43, compared to the other sowing windows. Generally mungbean harvest index is quite consistent; normally averaging around 0.3. This makes the November harvest index result highly significant. The pattern of differences are large enough to warrant further investigation of the data.

The September plant more than doubled its vegetative biomass after the crop started flowering. This is unusual given that the mungbean species is categorised as a vegetatively determinant crop; i.e. the crop stops producing vegetative biomass once the reproductive stage has started. Dry matter cuts were taken at the start of flowering and at final maturity. Stem and leaf was separated from the pods and weighed separately. This data was collected for both the September and October sowing windows (Figure 2).

The September sowing increased its vegetative biomass after first flower by 1.25 t/ha where as the October sowing only increased by 0.2 t/ha (Table 3). These results would suggest that conditions after flowering impacted differently on the plants' physiology.

It is generally accepted that mungbeans require 600 growing day degrees (GDD) to reach the start of flowering and 1200 GDD to reach maturity and desiccation. The GDD numbers recorded in this trial to first flower range from 554 to 645; reasonably close with the theoretical bench mark. It is also worth noting how it takes less calendar days to accumulate the same number of GDD as the sowing time gets later into the season (47, 39, 35).

The GDD from first flower to maturity is less consistent across the sowing times, with the October period showing a significant shortening of its reproductive period (25 days) and lower accumulation of GDD (1075). This is in contrast to the November sowing period where the reproductive period has extended out to 40 days and its accumulated GDD (1319) is well over the theoretical benchmark of 1200. This is despite the fact this time of sowing is planted later in the spring season and should be experiencing much higher daily mean temperatures than October.

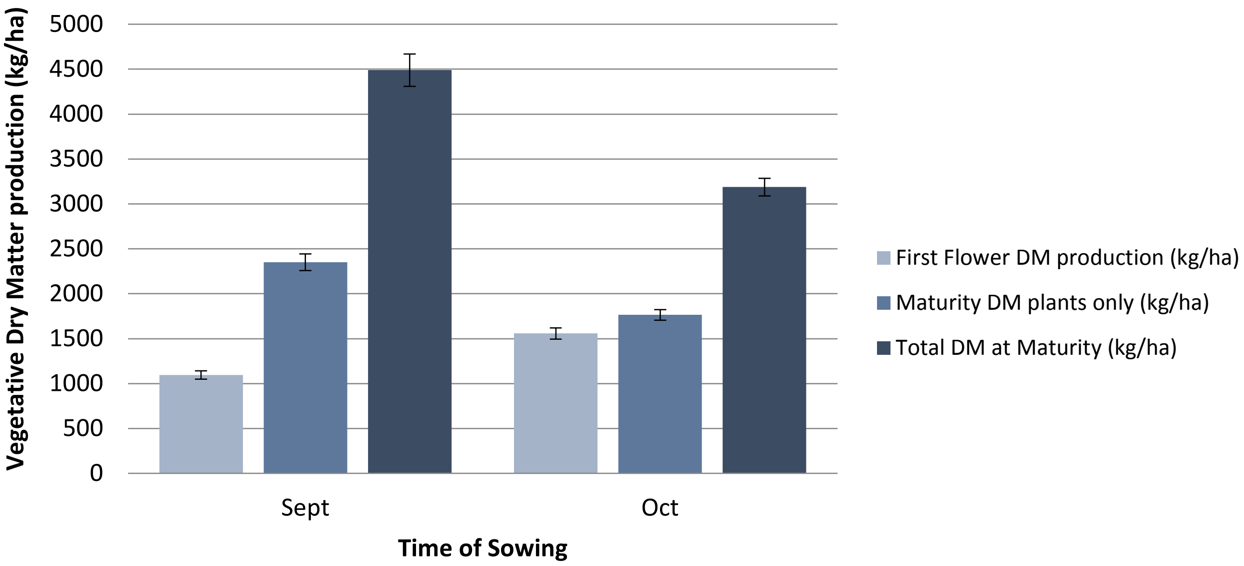


Figure 2. Differences in vegetative biomass from first flower to maturity in the first two planting dates

100 cm rows in September sowing time

All three sowing times were planted on similar stored moisture profiles. The main difference between October and the other two sowing times is the access to in-crop water during flowering and grain fill. Both September and November sowings had access to in-crop water, from either rainfall or irrigation, of over 100 mm; whereas October had only 15 mm of in-crop water from first flower to maturity (Table 3). This may explain why September put on more vegetative growth after first flower, and consequently more yield. It may also explain why October had such a short reproductive period and consequently lower grain yield.

There is some anecdotal evidence that water balance is one of the key limiting factors for mungbean production in dryland production systems, particular in CQ. Key weather drivers of water demand for the crop is relative humidity and temperature. These factors can be viewed in isolation (Figure 3) as a daily means which can be difficult to interpret; or they can be packaged together and expressed as a vapour pressure deficit (VPD) (Figure 4).

The difference between a saturated atmosphere and the actual level of humidity at a given temperature converted into vapour pressure and measured in kilopascals (kPa) is the VPD. The

Table 3. Summary of key physiological development periods for all three sowing times

TOS	Physiological stage	Date	Calendar Days	Growing Day Degrees (°C)	Rainfall (mm)	Irrigation (mm)	Starting PAWC (mm)
Sep	Planting	11/09/2015					124
	First Flower	27/10/2015	47	554	29	75	
	Desiccation	1/12/2015	81	1129	34	75	
Oct	Planting	20/10/2015					118
	First Flower	27/11/2015	39	645	50	75	
	Desiccation	23/12/2015	64	1075	15		
Nov	Planting	20/11/2015					119
	First Flower	25/12/2015	35	612	15		
	Desiccation	3/02/2016	75	1319	162		

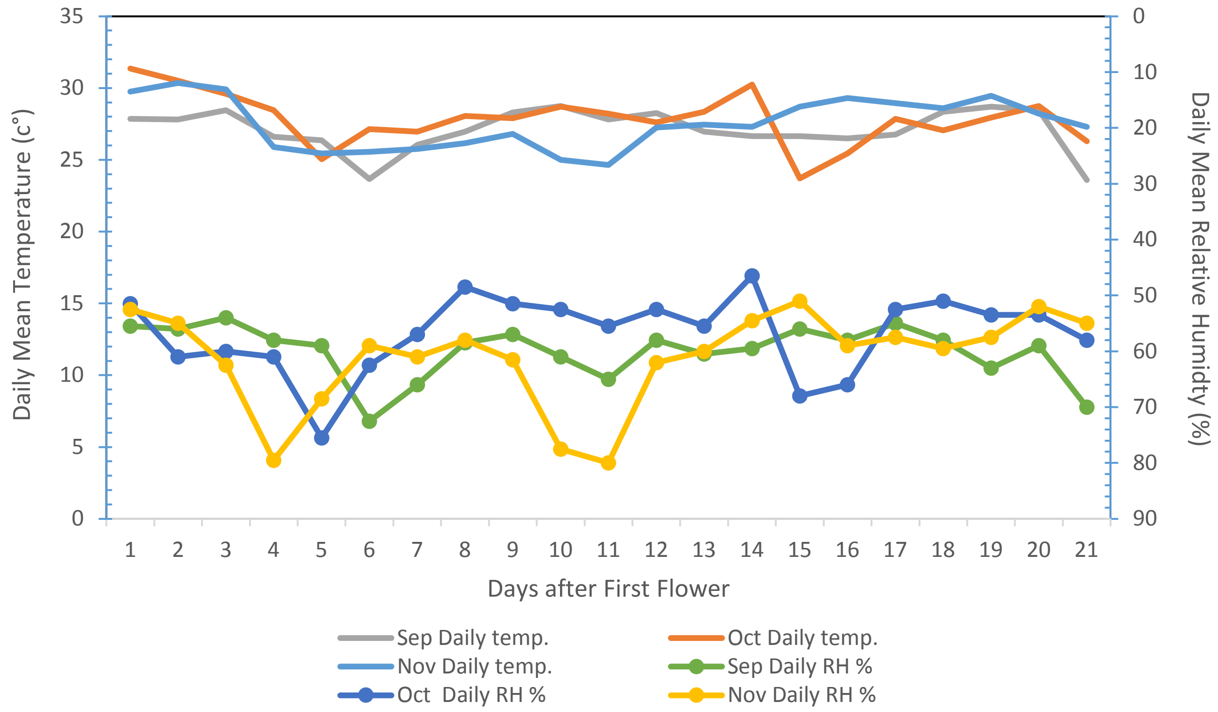


Figure 3. Comparison of the average daily temperature and average daily humidity across the three sowing times for the first 21 days after first flower

100 cm rows in November sowing time

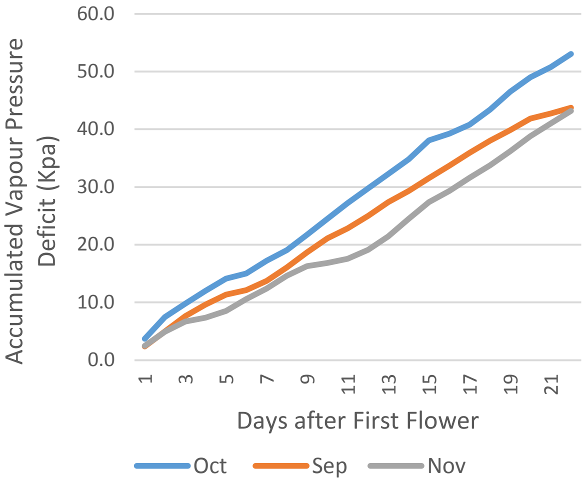


Figure 4. Comparison of the accumulated vapour pressure deficits (VPD) across the three times of sowing for the first 21 days after first flower

higher the air temperature; the more moisture can be held as vapour. Therefore the higher the temperature and the lower the humidity creates the highest VPD and consequently the strongest pull on transpiration of water from the leaf. This is a similar concept to Delta T in spraying terms where the higher the Delta T, the drier the air, the shorter the lifespan of a water droplet in the atmosphere.

In relation to the plant a high VPD means it must draw water faster and in greater amounts through its root system to maintain full turgor pressure in its leaf cells. If there is free in-crop water from rainfall or irrigation, then this water balance is easier to maintain, however if water is being dragged from stored soil moisture in a heavy clay soil then the plant may not be able to keep up with crop requirements.

Mean daily temperature data (Figure 3) would suggest that there were no clear differences between the three planting dates during the main flowering period of the crop. The relative humidity data does suggests some lower humidity conditions during key flowering period for the October sowing period.

The accumulated VPD data (Figure 4) shows a clear delineation between the conditions experienced by the October sowing time and the other two sowing periods. This means the October planting experienced higher evaporative conditions during the critical period of flowering and pod set with little in-crop rainfall to balance out the high demand for water by the crop. This data is reinforced by the average daily VPD measured during the daylight hours for the 21 day period after first flower (Table 4).

Table 4. Average daily VPD calculated from 15 minute weather station data across daylight hours

Time of sowing	Average daily VPD (kPa)
September	1.99
October	2.41
November	1.96

In summary, there is some evidence to suggest that the relatively low grain and dry matter yields sustained by the October time of sowing was influenced by a set of weather conditions that combined high evaporative (humidity X temperature) demand with limited availability of in-crop water. The September and November sowing times did not experience the same weather conditions and consequently produced higher grain yield and harvest index. This trial data is not conclusive or definitive and requires further data to confirm this pattern of response to weather conditions.

Implications for growers

There was a yield advantage (10-20%) in growing mungbeans on narrower rows (25-50 cm) where crops were achieving yields of between 1-1.5 t/ha. At these yield levels there was no advantage in higher populations, in fact this trial would suggest that there was a yield advantage in low populations; but this is the only trial data that supports this and caution needs to be taken when considering these results.

The influence of weather conditions on mungbean performance cannot be overestimated. There can be large changes in grain yield across spring sowing windows and while access to free water at critical times would seem to be the main influence on yield there is enough evidence to suggest that certain weather conditions also play a part in the delicate water balance of the mungbean plant on heavy clay soils. Avoiding high evaporative conditions during traditionally low rainfall periods will improve the reliability of yield for mungbean crops in CQ. Further field experiments are required to consolidate these findings.

Acknowledgements

The Queensland Pulse Agronomy Initiative (UQ00063) 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:	Queensland Agricultural Training College, Emerald
Crop:	Mungbeans (Jade-AUⓅ)
Soil type:	Black/Grey cracking Vertosol
In-crop rainfall:	240 mm
Fertiliser:	Supreme Z® at planting 30 kg/ha

Selected soil fertility characteristics for the trial site:

Depth Increments	Nitrate Nitrogen	Phosphorus Colwell	Sulfur	Exc. Potassium	Organic carbon	Conductivity	CEC
	mg/Kg	mg/Kg	mg/Kg	meq/100g	%	dS/m	meq/100g
0-10	24	49	16.5	1.02	0.70	0.083	38
10-30	20	21	12.5	0.65	0.54	0.083	38
30-60	11	3	14.0	0.45	0.44	0.061	38

Mungbean: impacts of time of sowing and irrigation on row spacing and population treatments in summer planted crops—Emerald

Doug Sands
Department of Agriculture and Fisheries

Research Question: *Are the effects of row spacing and population changed by time of sowing and soil water conditions in summer planted mungbeans?*

Key findings

1. Narrow rows (25 cm) produced a 24% yield increase over 100 cm rows in irrigated conditions.
2. Low plant populations (›15 plants/m²) reduced yields by up to 24% in all conditions.
3. Yields increased between 50–70% on average from additional in-crop irrigation on top of full soil water profiles at planting.
4. Yield declined in February time of sowing compared to January.

Background

Over the last two years the Pulse Agronomy Initiative (UQ00063) has been conducting experiments to quantify the impact of different row spacing and populations on dryland mungbean yields. Essentially these experiments have found very little response to population changes (10 to 40 plants/m²) and row spacing changes (25 cm to 100 cm rows). Most of this data has been collected across low yielding dryland sites (0.5 to 1.2 t/ha). Coincidentally the crop water use efficiency across these sites have been lower than expected and this has opened up more questions about the water uptake of the crop in relation to stored soil water and in-crop water supply.

Crop water balance issues are often impacted by weather conditions particular in Central Queensland (CQ). Mungbeans have a wide planting window in CQ, from September through to March. This wide planting window means the plant can experience very different weather conditions between spring (September, October, November) and summer (December, January, February). Therefore there are information gaps around not only the impact of row spacing and population in high yielding situations (›1.5 t/ha) but also the impact of weather and soil water conditions on crop physiology.

What was done?

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

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

December TOS, established populations on 25 cm rows, 15 plants/m² in foreground and 23 plants/m² in background

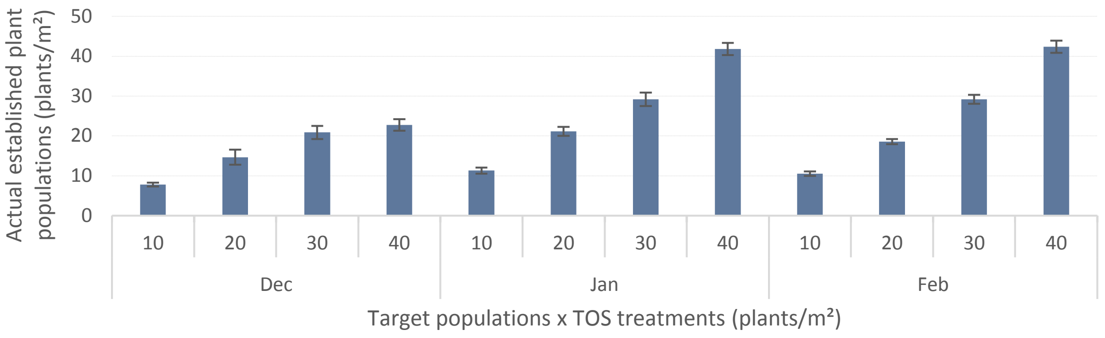


Figure 1. Target populations versus established populations across time of sowing

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

Dry matter cuts were taken at the start of flowering and at full maturity for January and February but only a maturity cut was taken for the December planting. Maturity dry matter cuts were split into pods and vegetative samples and dried separately before all the pods were thrashed out and weighed for a hand harvest yield assessment. Machine harvest yields were also measured and samples kept for analysis. Hand harvest samples were assessed for seed size.

Weather data was recorded throughout the trial from an OZ Forecast weather station positioned close to the trial site. This weather station takes readings every 15 minutes and records temperature, humidity, radiation, rainfall and evaporation.

Neutron probe tubes were installed in the 25 cm and 100 cm row plots for the January TOS. This included one population treatment (30 plants/m²) on both irrigated and dryland treatments across all three replicates. Readings were taken twice weekly at 10 cm increments down to a depth of one metre. Soil cores were also taken at planting and harvest for gravimetric soil water assessment and nutrient analysis.

Results

The results of this trial are reported in three parts.

1. the performance of row spacing and population treatments across both dryland and irrigated situations within each TOS
2. a closer examination of the soil water balance through the neutron probe measurements across both irrigated and dryland treatments
3. the impact of weather conditions on the performance of each TOS.

Table 1. Summary of key physiological development periods for all three sowing times

Time of Sowing	Physiological stage	Date	Calendar Days	Growing Day Degrees (°Cd)	Rainfall (mm)	Irrigation (mm)	Starting PAWC (mm)
Dec	Planting	18/12/2015					69
	First Flower	26/1/2016	39	695	85	100	
	#Desiccation	24/3/2016	97	1701	206	50	
Jan	Planting	13/1/2016					82
	First Flower	22/2/2016	40	734	181	50	
	#Desiccation	18/4/2016	96	1623	38	100	
Feb	Planting	18/2/2016					142
	First Flower	23/3/2016	34	609	33	100	
	#Desiccation	29/4/2016	71	1132	5	50	

#Note: Desiccation decisions were made based on the maturity of pods in the dryland treatments

Due to the structure of the trial the TOS treatments cannot be compared directly on a statistical basis as they have been set up as side by side, non-randomised blocks (individual trials), however a broad assessment of common treatments within each TOS can give us some insight into performance in relation to weather conditions.

Time of sowing–December

The Growing Day Degrees (GDD) at maturity for this time of sowing has blown out considerably from the theoretical mean of about 1200°Cd even though the flowering interval was close to the 600°Cd requirement (Table 1). This may be due to an extended flowering period because of an abundance of in-crop water. Unfortunately the 100 mm of irrigation supplied to the irrigation treatments occurred only five days before two weeks of extended rainfall (173 mm). This meant that the difference between irrigation and dryland treatments is almost non-existent. The extended period of cloudy wet weather and temporary waterlogging interfered with normal flowering. The plant tried to compensate by extending its flowering period and having flushes of flowers occurring almost simultaneously.

Consequently the differences between irrigated and dryland plots are not significantly different (Figure 2) given the dryland plots received 290 mm of in-crop rainfall (Table 1). The variability in the data makes it difficult to draw too many conclusions. There is a significant pattern for the lowest populations causing a yield penalty in both the irrigated and dryland treatments although this is more significant in the irrigated treatments with the trend being linear across the total range of populations (13.26 kg/ha per extra plant/m², lsd = 121.3).

There is no significant difference between row spacing on its own, however there was a small significant interaction between row spacing and irrigation treatments (lsd = 217.6) where the major difference was between the irrigated 25 cm and 50 cm row spacing (367 kg/ha). This is in contrast to previous trials and may be a reflection that the yields were impacted by waterlogging with few treatments achieving over 1.5 t/ha.

Time of sowing–January

There were no significant differences for row spacing on its own (Figure 3) across the January TOS. However population was significant with the lowest population causing a significant drop off in yield which was 459 kg/ha lower than the highest population (lsd = 131.1). Despite a full moisture profile before flowering, all dryland yield treatments are under 1.5 t/ha with the average being 1297 kg/ha.

In contrast the irrigated treatments averaged 2201 kg/ha; a 70% increase in yield over the dryland treatments. This difference is further enhanced by the interaction with both row spacing and population (lsd = 477.1). There are linear responses to population increases in the 50 cm and 100 cm rows and a significant quadratic response to population in the 25 cm rows. This indicates a major drop off in yield at low populations (11 plants/m²) on 25 cm rows in the irrigated treatments (Figure 3). Differences in yield in the 21, 29 and 42 plants/m² are generally not significant.

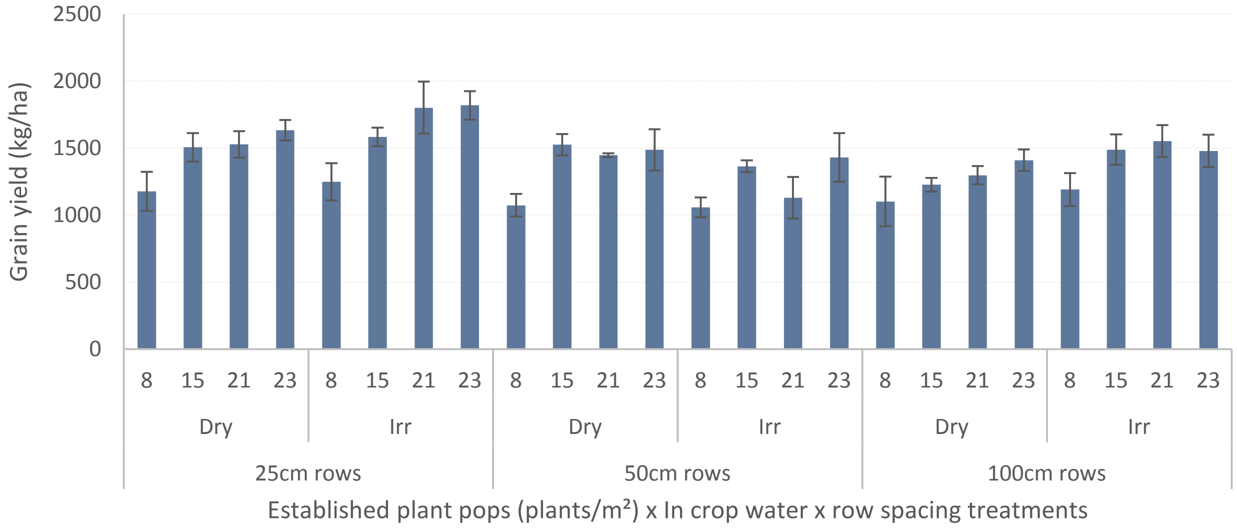


Figure 2. Comparison of row spacing, plant population and in-crop water conditions for the December sowing

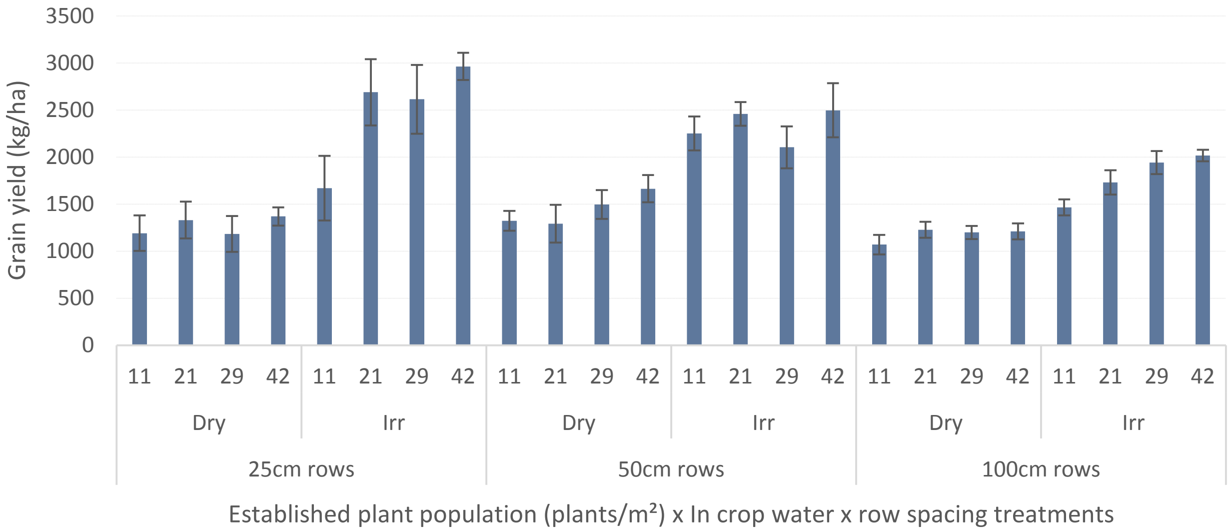


Figure 3. Comparison of row spacing, plant population and in-crop water conditions for the January sowing

The yield increase between dryland and irrigation treatments have been most dramatic in the 25 cm row spacing with yield more than doubled in the 21, 29 and 42 plants/m² and some plots tipping 3000 kg/ha. This would seem to be extreme given that both the dryland and irrigated treatments received 180 mm of rainfall in the first four weeks after planting. Therefore most of the yield improvement has been gained from the 150 mm of irrigation that occurred from first flower to maturity where as the dryland treatments had 38 mm of in-crop rainfall.

All the irrigated plots achieved yields above 1.5 t/ha except for the 100 cm rows at the lowest population. Overall the major advantage with the higher yielding crop has come from narrow rows with significant differences between 25 cm rows and 100 cm rows at all populations (lsd = 477).

Time of Sowing–February

There has been a similar pattern of response in the February yield data as there was in the January TOS (Figure 4). The response to irrigation has not been as large with average increase of 643 kg/ha (54%, lsd = 136). However it has been consistent across all population and row spacing treatments with a 61% increase in yield across 25 cm and 50 cm rows and a 43% increase across 100 cm rows. Overall the irrigated yields have not reached the same levels as the January planting date with only the 50 cm row treatments getting above 2 t/ha. The dryland yields are slightly lower than the January TOS with an average of 1182 kg/ha.

There has been a very flat response to row spacing in general with the only significant difference being between the 50 cm rows and the 100 cm rows (lsd = 209.9) . The main

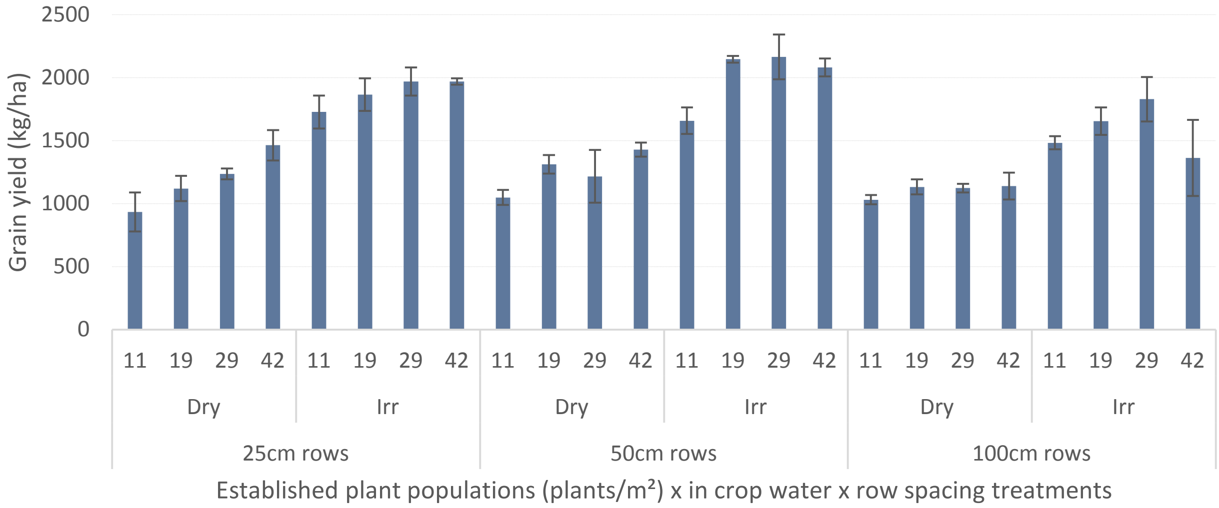


Figure 4. Comparison of row spacing, plant population and in-crop water conditions for the February sowing

25 cm row spacing plots across three times of sowing: (left to right) December, January, February

response to population has been in the lowest populations (11 plants/m²) with a significant drop off in yield compared to the other three population treatments (lsd = 122.2). Although the irrigated treatments have provided an improvement in yield from the narrow rows (25 cm, 50 cm) over the 100 cm rows (averaging 23% difference); this was just outside the 5% significant levels. Population changes in the irrigated treatments have provided a curved quadratic response to yield with the lowest population showing the greatest yield decline and the differences between the 19, 29 and 42 plants/m² are generally not significant.

In summary, plant populations and row spacing had a significant impact on grain yields in the irrigated treatments but not the dryland treatments except for the lowest population where there was a significant yield penalty. Generally, yield was maximised in the 25 cm and 50 cm row spacing with the 100 cm row spacing incurring a significant yield penalty in mainly irrigated circumstances. Irrigation has made large differences in grain yield in January and February sowing times, despite soil water profiles being basically full at or near planting.

Soil water impacts

The January TOS was not planted on a full profile of soil moisture but within two weeks of planting, the trial received 180 mm of rainfall over a period of two weeks. This rainfall effectively filled the profile so both the irrigated and dryland treatments had similar levels of stored moisture at least two weeks before flowering started.

There were three irrigations applied to the irrigated treatments, with each irrigation supplying 50–60 mm of water; approximately two weeks apart starting from first flower. The first irrigation shows it had little impact on the stored moisture profile (Figure 5) whereas the second and third irrigations increased soil moisture profile by 25 mm and 50 mm respectively.

Water uptake for all treatments increases rapidly from first flower with the plant drawing 20 mm per week for the next three weeks (Figure 5). After this point the dryland treatments started reducing their water uptake while the irrigated treatments continued at this rate right through to maturity. Both the irrigated and dryland

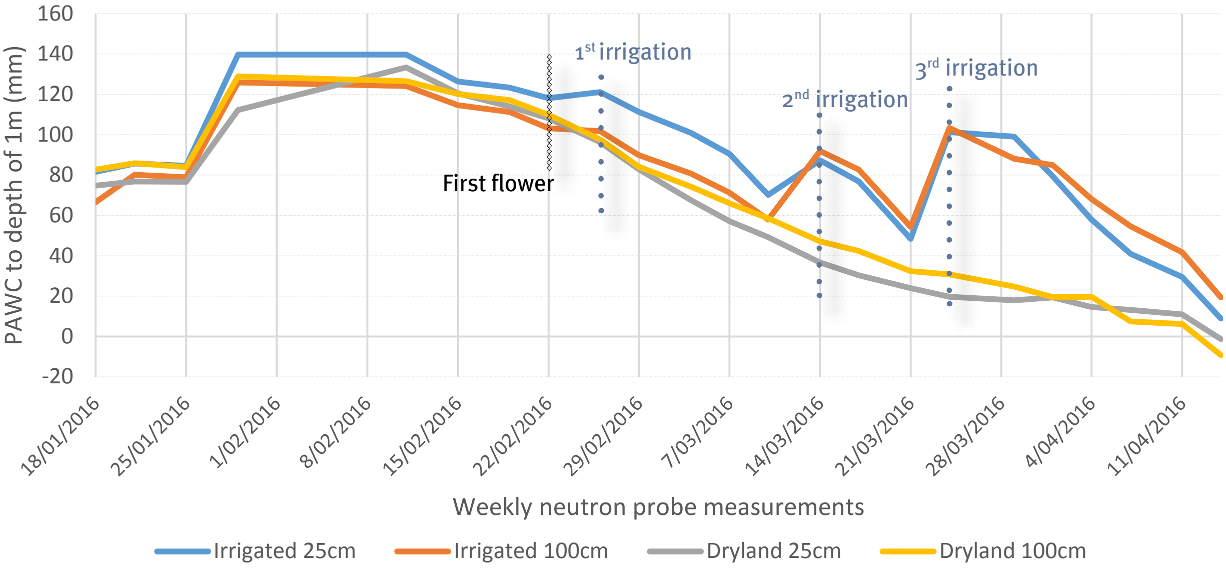


Figure 5. Plant available water content for January time of sowing for irrigated and dryland treatments across narrow and wide row spacing as measured using a neutron probe

Table 2. Comparison of crop water use efficiency between irrigated and dryland treatments

Soil Water Status	Row spacing (cm)	Starting PAW (mm)	Irrigation + Rainfall (mm)	Soil water uptake (mm)	Grain yield (kg/ha)	Theoretical Crop WUE (kg/mm/ha)	Measured soil water uptake Crop WUE (kg/mm/ha)
Irrigated	25	82	368	205	2485	5.52	12.12
	100	82	368	197	1790	3.98	9.09
Dryland	25	82	218	135	1269	4.23	9.40
	100	82	218	143	1177	3.92	8.23

treatments drew down the profile to similar levels which was unexpected as logic would suggest that the irrigated treatments would have no need to draw down the soil profile as hard as the dryland treatments.

Based on the neutron probe measurements the irrigated treatments used 70 mm (25 cm rows) and 55 mm (100 cm rows) more plant available water (PAW) than the dryland treatments for the same row spacing. However the 25 cm irrigated treatments produced an extra 1200 kg/ha of grain over its dryland counterpart and the 100 cm irrigated treatments produced an extra 600 kg/ha of grain.

One of the outcomes from mapping water uptake by the plant through an instrument like the neutron probe is it highlights the level of intake efficiency from additional in-crop water. The comparison between soil water uptake (neutron probe data) and irrigation plus rainfall (Table 2) shows that only 45% of the additional in-crop water is actually contributing to plant available stored moisture. This then makes the theoretical crop water use efficiency (WUE) calculation unrealistic since additional rainfall is incorporated at 100% efficiency.

There are major factors that impact on the efficiency of in-crop rainfall/irrigation contribution to stored soil water. These factors include intensity of rainfall, current soil moisture status and crop canopy development. A good example of this is how each subsequent irrigation application had an increased intake efficiency as the soil moisture status of the profile declined (Figure 5).

Another outcome from crop WUE figures (Table 2) is the major increase in WUE from the irrigation treatments. This was not expected as in most crops a dryland system will work harder to access the soil moisture than an irrigated crop needs to, however in this situation not only did the irrigated treatments have a yield increase from the extra water added but the crop also used that added water more efficiently.

The difference in WUE between irrigated and dryland treatments is smaller in the 100 cm row comparison than it is in the 25 cm rows (Figure 5). There is no definitive answer for this but one theory is that the 25 cm rows dried out the surface profile far more evenly and faster than the wider rows, meaning the plant can take better advantage of any additional in-crop water. This then also leads to the idea that a mungbean plant can perform far more efficiently if it can extract all its water needs from the top 40-60 cm of the profile, especially if weather conditions are causing high evaporative demands on the crop. The crop can extract water from deeper down the profile but this is a much slower uptake and requires more energy from the plant.

Weather conditions

Grain yield performance was similar across the three TOS for all the dryland treatments, however there were large differences between the irrigated treatments (Figure 6). The flowering period for the December planting was impacted by water logging conditions which may explain much of the result for this TOS. Both the January and February plantings had good conditions for flowering with no extreme temperatures to

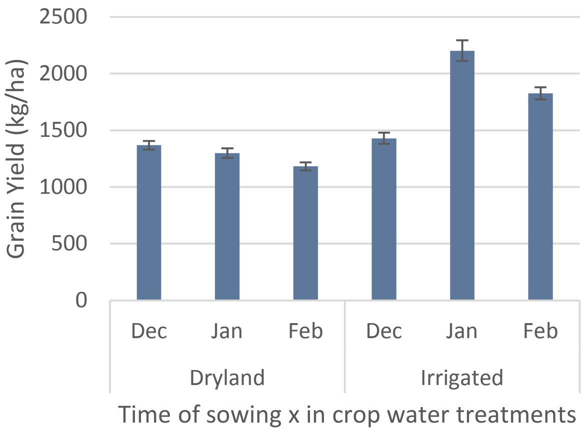


Figure 6. Relative grain yield performance between the dryland and irrigated treatments for each time of sowing

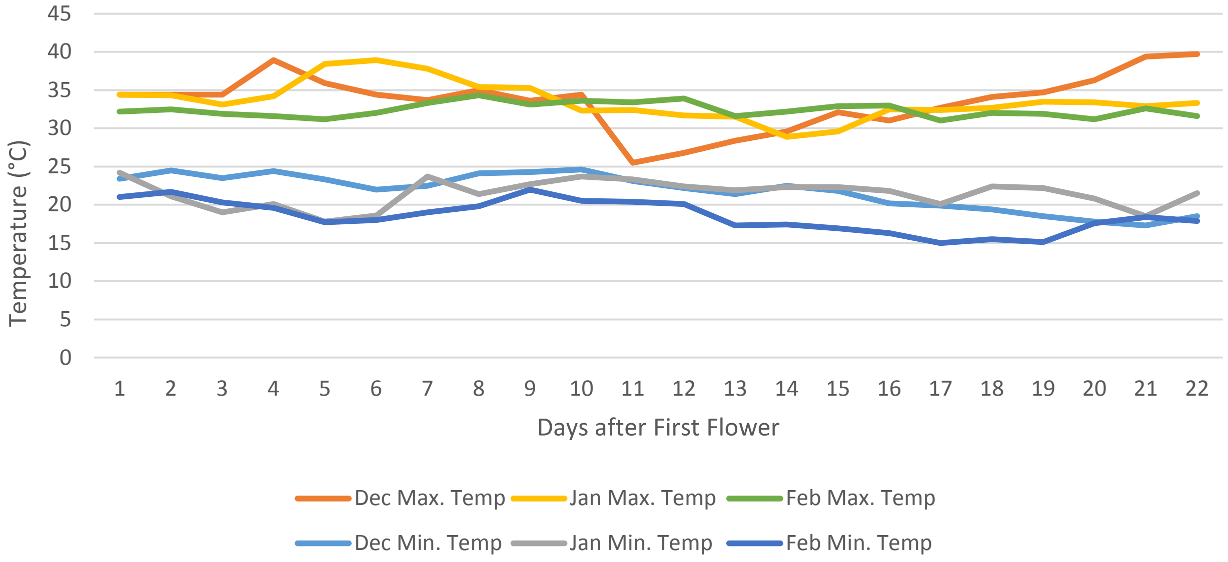


Figure 7. Comparison of max. and min. temperature for first three weeks after flowering, across time of sowing

contend with (Figure 7). Minimum temperatures for February TOS were mild compared to the other two TOS (21°-15°C) and the minimum daily temperature did not go below 23°C. This should have meant that the February time of sowing should have performed better on stored moisture conditions than the earlier time of sowing; this was not the case. The dryland treatments performed slightly worse and the irrigated treatments were significantly smaller than January (Figure 6). It was also noticeable that the flowering period for February was much shorter than the other two sowing times (Table 1).

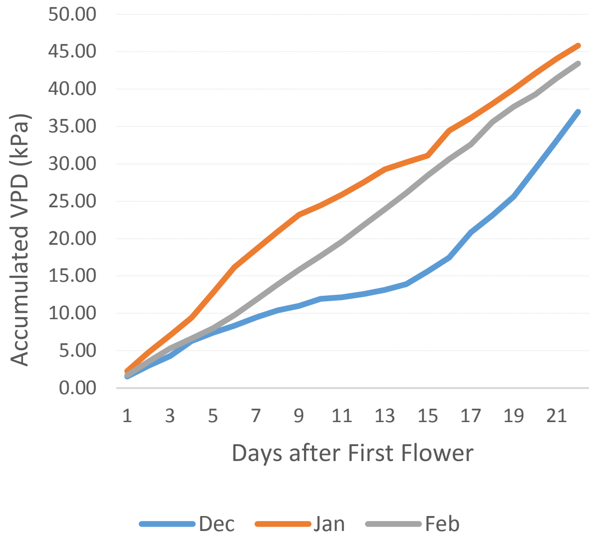


Figure 8. Comparison of vapour pressure deficit across times of sowing for the first three weeks of flowering

The other weather conditions to consider when comparing the February TOS are the relative vapour pressure deficit (VPD) and the incident solar radiation. VPD is a measure of the evaporative demand on the crop and uses a combination of temperature and relative humidity to calculate the relative vapour pressure conditions on the crop (the higher the VPD the drier the atmosphere). The accumulated daily VPD data (Figure 8) shows that January and February had similar flowering conditions in relation to vapour pressure, although January had slightly drier conditions in the second week. The December TOS had comparatively mild VPD conditions which was a consequence of wet conditions at the time. The daily solar radiation data (Figure 9) shows February had a consistently lower level of daily radiation for much of the flowering period where as the earlier sowing times had more erratic levels of radiation, but on average much higher.

Examining a range of weather factors shows the main difference in conditions between the January and February times of sowing is a much lower level of incident radiation, this could be due to consistent overcast conditions or shortening day length; or a combination of the two. This seems to be the only explanation for the reduction in irrigated comparative grain yields across January and February times of sowing.

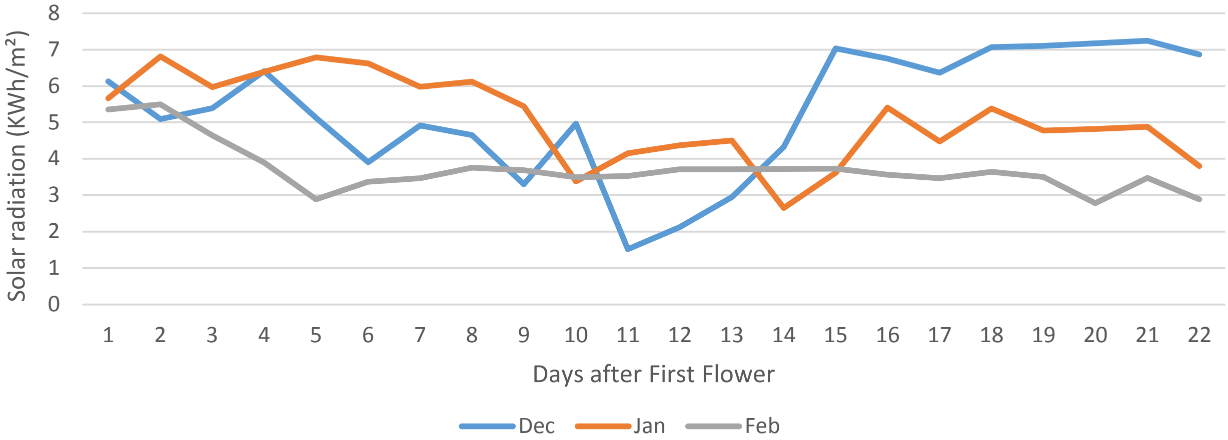


Figure 9. Comparison of solar radiation across times of sowing for the first three weeks of flowering

Implications for growers

Narrow rows (25-50 cm) deliver a yield advantage in high yielding conditions (>1.5 t/ha) across a range of weather conditions. This yield advantage can range from 15 to 24% over 100 cm rows. There is a definite yield penalty for low plant populations especially in high yielding situations. Plant populations of 8-11 plants/m² can cause yield losses of between 18-24% depending on the yield potential. Plant populations in a range from 19 to 42 plants/m² have very similar yields across most planting situations.

The ability of mungbean to produce yields above 1.2 t/ha on good stored moisture profiles is questionable. Timely in-crop water can double yields (on 25 cm rows) even when there is good stored moisture conditions prior to flowering. In-crop water supply also seems to promote much higher water use efficiency by the plant (extra 3 kg/mm/ha).

Weather conditions will always have an impact on mungbean production, however which parts of the weather have the most impact is yet to be determined. Waterlogging, temperature and humidity at flowering can all have an impact, however solar radiation intensity and day length may also play a role in limiting yield for later sowing times. Weather impacts change from season to season so more data is required from subsequent seasons before specific patterns can be confirmed.

Acknowledgements

The Queensland Pulse Agronomy Initiative (UQ00063) 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: Queensland Agricultural Training College, Emerald
Crop: Mungbeans (Jade-AUⒹ)
Soil type: Black/Grey cracking Vertosol
In-crop rainfall: 291 mm
Fertiliser: Supreme Z® at planting (30 kg/ha), CK 55 (S)® pre-plant (150 kg/ha)

Selected soil fertility characteristics for the trial site:

Depth Increments	Nitrate Nitrogen	Phosphorus Colwell	Sulfur (KCL-40)	Exc. Potassium	Organic carbon	Conductivity	CEC
	mg/Kg	mg/Kg	mg/Kg	meq/100g	%	dS/m	meq/100g
0-10	10	64	7.4	0.11	0.73	0.044	34
10-30	11	9	11.4	0.44	0.37	0.057	36
30-60	8	3	10.1	0.36	0.33	0.057	38

Chickpea: changes in canopy development and yield across row spacing, variety and time of sowing—Emerald

Doug Sands
Department of Agriculture and Fisheries

Research Question: *How does a late sowing window impact on the canopy development and water use of chickpeas across a range of populations, row spacing and varieties?*

Key findings

1. August sowing reduced grain yield by 1 t/ha (33% reduction on July sowing).
2. No change in harvest index across times of sowing, row spacing or population.
3. Faster canopy development in late sowing but less dry matter production.
4. No yield differences between varieties.

Background

This trial was conducted as part of the UQ00067 Pulse Agronomy Initiative, which is focused on examining the Genetic x Environment x Management (GxExM) interactions of growing chickpeas in Central Queensland (CQ). Previous trial work has indicated some variation in harvest index between different planting times and row spacing. This has shown some inconsistency in the relationship between dry matter production and grain yield. This trial aimed to provide more detailed data around the development of the plant canopy (biomass) and how it is influenced by row spacing, time of sowing, population and soil water conditions.

What was done?

The trial was conducted at the Department of Agriculture and Fisheries research facility located on the Queensland Agricultural Training College farm close to Emerald on the Central Highlands. The treatments involved were;

- 2 x time of sowings (4 July and 1 August)
- 2 x row spacing (50 cm, 75 cm)
- 2 x populations (15 and 30 plants/m²)
- 4 x varieties (Kyabra⭆, PBA Seamer⭆, PBA Pistol⭆, PBA HatTrick⭆)

The trial design was a modified split–split plot. The time of sowing (TOS) was used as the main blocks and these were split into two row spacing blocks which were in turn split into eight sub plots where the population x variety treatments were randomly assigned. Individual plots were 4 m wide x 24 m long. Supreme Z® was applied as a starter fertiliser at a rate of 30 kg/ha with the seed at planting. Inoculant was applied at planting as a water injection treatment. Both the July and the August sowings were planted on rainfall events. There were no in-crop irrigations applied to either of the plantings.

Starting water and nutrient soil cores were taken at planting and establishment counts were done after emergence. Multiple light interception measurements were taken around flowering and total dry matter was measured at maturity when 90% pods were brown. Neutron probe tubes were installed in both row spacing treatments in one variety (PBA HatTrick⭆) and one population (30 plants/m²). This was done across both sowing dates and all three replicates. Measurements were taken twice a week at 10 cm increments. Unfortunately the data collected was corrupted by an undiagnosed problem within the neutron monitor. Consequently most of this data is unusable. Plot yields were obtained by a plot harvester and seed samples were collected from each plot for chemical analysis. Soil cores were taken after harvest for gravimetric soil moisture measurements.

Table 1. Key agronomic data for both sowing dates

Time of Sowing	Date Planted	Days to Flower	Growing Day Degree to Flower(°Cd)	Days to Maturity	Growing Day Degree to maturity (°Cd)	Starting PAW to 120 cm depth (mm)	Rainfall (mm)
July	4/07/2016	57	943	95	1714	118	145
August	1/08/2016	56	1032	94	1888	119	65

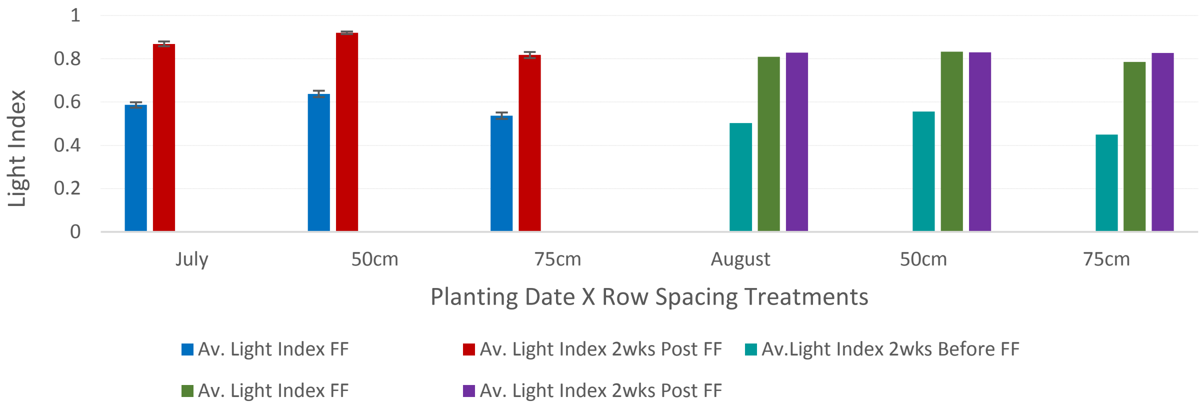


Figure 1. Comparison of light index data across TOS and row spacing treatments

Results

The agronomic data (Table 1) shows no real differences in days to flowering or starting plant available water (PAW) for both sowing times. There were slight increases in growing day degree (GDD) units at flowering and maturity for the August sowing time, which is not surprising given the proximity to warm spring temperatures. The biggest difference between the two sowing times was the amount of in-crop rainfall, with the August sowing time receiving less than half the rainfall that July received.

75 cm rows in July sowing period at start of flowering (the crop has not reached full canopy cover)

The light index data shows a difference in canopy development between July and August sowing times (Figure 1). The July sowing time only reached a light index of 0.6 by start of flowering (blue bars) whereas the August sowing time reached a light index of 0.8 by start of flowering (green bars). Within two weeks of first flower the July sowing time had reached a light index of 0.9 (red bars) where as the August sowing time had not changed at all (purple bars). The speed of canopy closure was much faster in the later planting date however dry matter production was much smaller (Figure 4), indicating speed of canopy closure is not a good indicator of total dry matter production even though theoretically canopy development should improve light interception and energy accumulation.

The most significant differences in grain yield occurred across the main treatment effects of TOS and row spacing. The July TOS achieved an average yield advantage of 1062 kg/ha or nearly a 50% gain over the August TOS (Table 2).

Table 2. Significant differences across main treatments

Variable	Treatment	Mean yield (kg/ha)	Difference (kg/ha)	LSD (P=5%)
TOS	July	3215	1062	374
	August	2153		
Row spacing (cm)	50	2772	178	100
	75	2595		
Population (plants/m²)	15	2659	49	57
	30	2708		

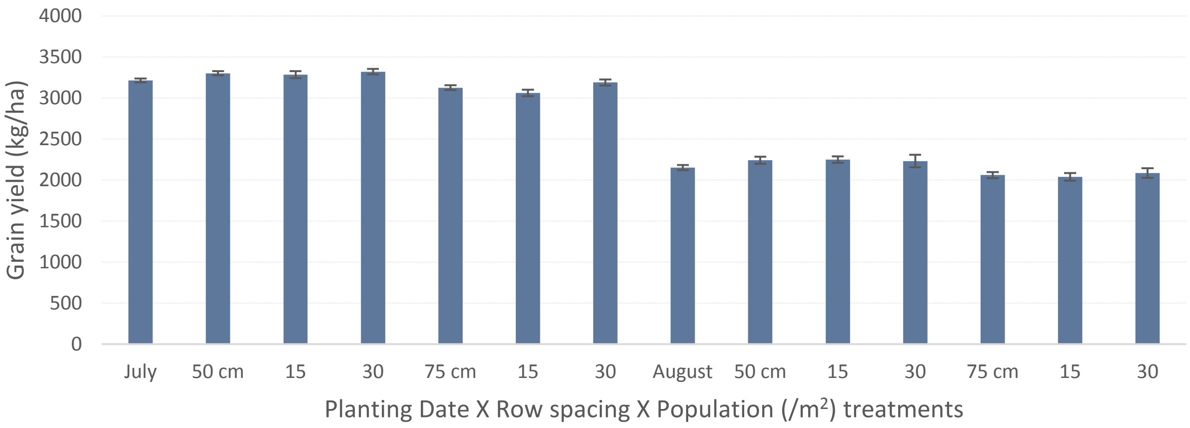


Figure 2. Grain yield comparison between TOS, row spacing and population treatments

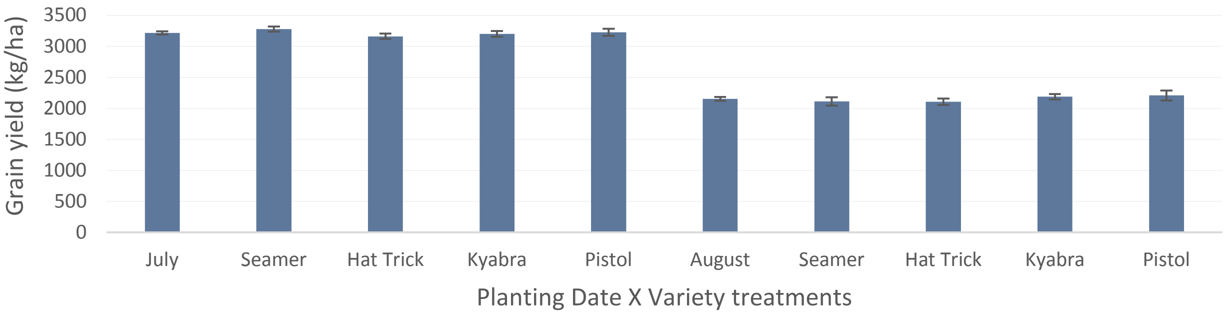


Figure 3. Grain yield comparison between TOS and variety treatments

Table 3. Variety comparison across TOS treatments

Variable	Treatment	Mean yield (kg/ha)	LSD (P=5%)
July	PBA Seamer ⅾ	3275	295
	PBA HatTrickⅾ	3159	
	Kyabraⅾ	3199	
	PBA Pistolⅾ	3225	
August	PBA Seamerⅾ	2112	295
	PBA HatTrickⅾ	2105	
	Kyabraⅾ	2186	
	PBA Pistolⅾ	2207	

This advantage in yield was very consistent across both row spacing and population (Figure 2). The 50 cm row spacing had a small average advantage of 178 kg/ha or nearly 7% gain over the 75 cm rows (Table 2). This was also consistent across population and TOS treatments (Figure 2). There were no significant differences across populations or varieties (Tables 2 and 3) as a main effect nor were there any significant interactions across TOS or row spacing (Figures 2 and 3).

Dry matter production was significantly higher in the July TOS (2272 kg/ha, l.s.d = 432) and there was also an interaction between row spacing and the August TOS (Figure 4). The 50 cm rows had a 530 kg/ha increase over the 75 cm rows (l.s.d = 408) however there were no significant differences in the July TOS. Remarkably there was no significant differences in harvest index across TOS (Figure 5) despite there being a big difference in grain yield. This uniformity across all treatments in harvest index at a historically high level (0.45 or better) would suggest that plants were performing at or close to their physiological potential across TOS, row spacing and population.

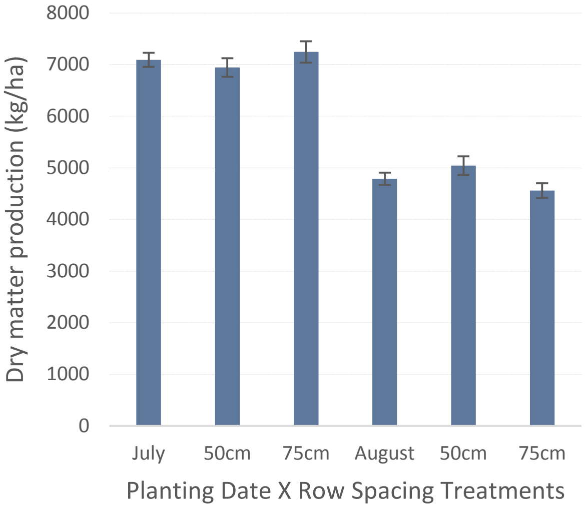


Figure 4. Comparison of dry matter production across TOS and row spacing treatments

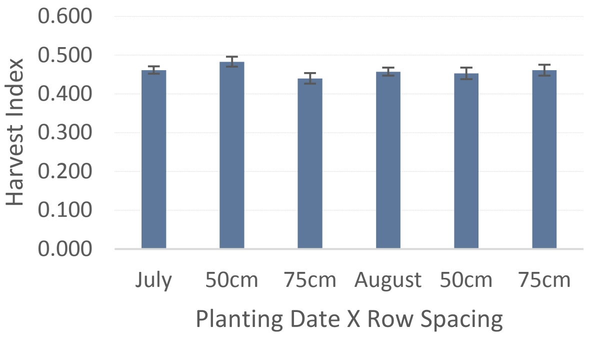


Figure 5. Comparison of harvest index across TOS and row spacing treatments

The soil water data (Figure 6) shows the August sowing time (red bars) dragging more moisture out of the profile in the top 60 cm, averaged over all the treatments. This lines up with the differences for in-crop rainfall (Table 1). Another aspect to this is that in the lower part of the profile (90-120 cm) the July planting actually extracted more moisture from this layer. This could be attributed to slower growing conditions where the plant had more time to extract small amounts from these deeper layers or more energy to devote to water extraction.

There were (Figure 6) no clear differences between the row spacing (50 cm and 75 cm) treatments in water uptake, nor any clear indicator of any preference of where plant roots extract moisture (under the row or between the row). The only exception is that within the top 30 cm of the profile the interrow area seems to have more moisture extracted than under the row, across both row spacing.

Implications for growers

Under late sowing conditions there was a large yield penalty to planting in August (1 t/ha) and this may be related to a large difference in dry matter production (>2 t/ha); consequently harvest index remained uniform across both planting dates (0.45). This would indicate that both sowing times achieved their physiological potential. In relation to late sowing of chickpeas it could be inferred that the August sowing time is getting too late to optimise yields.

Although days to maturity were similar, growing day degree accumulation indicated that the later sowing experienced some warmer conditions, particularly after first flower. This may have also influenced the rate of canopy development. Light index measurements would indicate faster canopy development in the later sowing time but this was not associated with higher dry matter production. This situation in the late plant would favour a narrow row configuration (smaller interrow space to cover) and better dry matter production over wide rows.

Lack of in-crop rainfall during the flower and fruit set period would seem to be the main factor in reducing the yield of the later sowing time, although there may have been other weather factors (day length, vapour pressure deficit and temperature) that influenced dry matter production, canopy development and abortion of flowers. Soil moisture extraction data would indicate that less rainfall put pressure on the plant to extract more soil water in the later

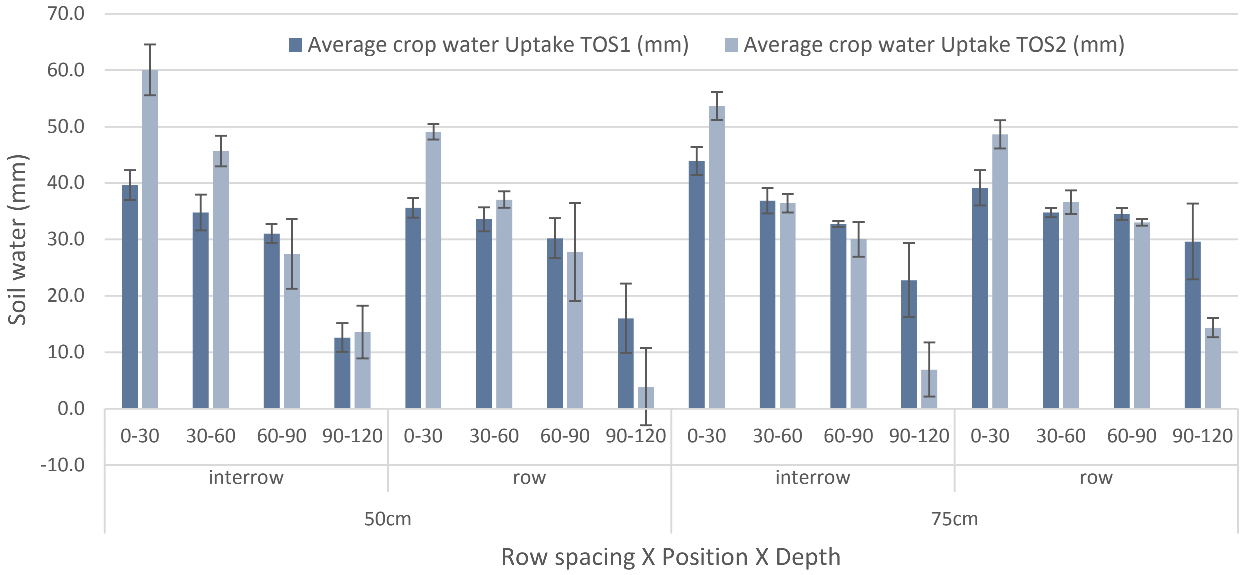


Figure 6. Comparison of soil water uptake data across row spacing and time of sowing treatments Measurements were taken from between the rows (interrow) and on the plant row (row)

time of sowing particularly in the surface profile (0-60 cm) but less in the deeper zones (90-120 cm).

There was a small advantage in yield for narrow row spacing (50 cm) of between 4-8% across both times of sowing. This was only in comparison to 75 cm rows and not 100 cm rows, which may have shown a bigger difference. This is a rare result for CQ growing conditions as most trials over the last two years have not shown any major differences. The lack of any significant differences between population treatments (15-30 plants/m^2) reinforces the data collected from previous CQ trials that the plant can compensate for small changes in population.

Overall this was an exceptional year for chickpea production with good in-crop rainfall and a mild start to the spring. The data produced in this experiment needs to be viewed in relation to other experimental data collected across different seasons. There is no doubt chickpeas in CQ can produce very good harvest index values with later times of sowing but there is a limit to how late we can plant for the best yield potential. Water extraction seems to be the biggest limiter to yield against other weather influences and narrow rows seem to have more benefit in later times of sowing.

Acknowledgements

The Queensland Pulse Agronomy Initiative (UQ00063) 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:	Queensland Agricultural Training College, Emerald
Crop:	Chickpeas (multiple varieties)
Soil type:	Black /Grey cracking Vertosol
In-crop rainfall:	Jun-16: 73 mm Jul-16: 83 mm Aug-16: 16 mm Sep-16: 33 mm Oct-16: 13 mm Nov-16: 15 mm
Fertiliser:	Supreme Z® at planting (30 kg/ha)

Selected soil fertility characteristics:

Depth (cm)	Nitrate N	Colwell P	S (KCl-40)	Exc. K	BSES P	CEC
0-10	21	51	8	0.81	91	33
10-30	17	14	9	0.40	33	33
30-60	11	4	11	0.32	17	34

Difference in maturity between July and August TOS

July TOS one week after first flower

Very wet start to July TOS, 16 days after sowing

July TOS one week into flowering

Chickpea: impacts of irrigation and foliar nitrogen on late sown crops—Emerald

Doug Sands
Department of Agriculture and Fisheries

Research Question: *Does additional water and nitrogen improve grain yield in late sown chickpeas?*

Key findings

1. Supplementary irrigation improved yield by 29% across all treatments.
2. No varietal difference in performance across treatments.
3. No response to foliar nitrogen applications.

Background

This trial was conducted as part of the UQ00067 Pulse Agronomy Initiative, which is focused on examining the genetics by environment by management (GxExM) interactions of growing chickpeas in Central Queensland (CQ). Previous trial work has indicated some variation in harvest index between different planting times and row spacing; indicating some inconsistency in the relationship between dry matter production and grain yield.

It has been observed that chickpeas in CQ mature very quickly in early spring which then leads to plant die back prior to harvest. This has been a convenient trait since it avoids the requirement of a pre-harvest desiccation. Current thinking is that this maturity and die back is a result of increasing temperature sensitivity, similar to most winter cereals.

Previous time of sowing trials (TOS) have indicated that timely rainfall can allow the plant to develop normally in setting flowers and filling grain during a time when temperature has been increasing. This trial was designed to develop more detailed data around the development of the chickpea plant in a late time of sowing (August) when it would be setting grain in a traditionally warmer and drier time of the year. The addition of in-crop irrigation and foliar nitrogen across several varieties will test whether the plant is more sensitive to water supply or temperature when it matures in warmer spring conditions.

What was done?

The trial was conducted at the Department of Agriculture and Fisheries research facility located on the Queensland Agricultural Training College farm close to Emerald on the Central Highlands. The treatments involved were:

- 2 x in-crop water treatments (dryland and supplementary irrigation). Irrigation was supplied as overhead sprinklers applying 50 mm of water. Irrigation was applied three times approximately 21 days apart with the first application going on at first flower
- 4 x foliar nitrogen (N) treatments (control, 1 application, 2 applications, 3 applications). Urea was mixed up into a solution equivalent to 10 kg N/ha applied at a rate of 200 L/ha. This solution was applied once, twice or three times approximately 20 days apart depending on the treatment. The first application was done approximately 10 days before first flower
- 4 x varieties (Kyabra⏀, PBA Seamer⏀, PBA Pistol⏀, CICA1303)

This trial design was a modified split – split plot. Irrigation and dryland treatments were used as the main blocks and these were then split into four variety treatments which were then in turn split into four foliar treatments. Individual plots were 4 m wide x 24 m long and they were replicated three times. All treatments were planted on 50 cm row spacing at 30 plants/m² and each row of plots was separated by a two metre buffer strip that was planted on 100 cm rows. The trial was planted on 1 August with 30 kg/ha of Supreme Z® applied with the seed. Inoculant was applied at planting as a water injection treatment. This trial was planted on rainfall.

Starting water and nutrient soil cores were taken at planting and establishment counts were done after emergence. Multiple light interception measurements were taken around flowering and total dry matter was measured at maturity when 90% pods were brown. Plot yields were obtained by a plot harvester and soil cores were taken after harvest for gravimetric soil moisture measurements. Individual plant mapping was also done on those untreated foliar N plots and those plots that had three foliar applications from the one variety (PBA Seamer⫚).

Results

Grain yield data shows a strong response to irrigation applications with an average yield gain of 656 kg/ha (29.5 %) for the irrigated plots across all treatments (l.s.d = 336). There were no significant differences across variety (Figure 1) or nitrogen foliar applications (Figure 2). It is worth comparing yields to a neighbouring chickpea trial investigating various times of sowing (page 83).

The best performing irrigation treatments were achieving 3000 kg/ha which is 215 kg/ha less than the July TOS average (3215 kg/ha). The August TOS plots averaged 2153 kg/ha which is very similar to the dryland yield data from this trial which averaged 2223 kg/ha. This comparison further supports that planting chickpeas in August will result in a reduction in yield potential. This data indicates that the soil moisture conditions improved the outcome of this late planted crop by almost 30% during a time when flowering and grain fill was occurring in increasing daily temperatures (Figure 3).

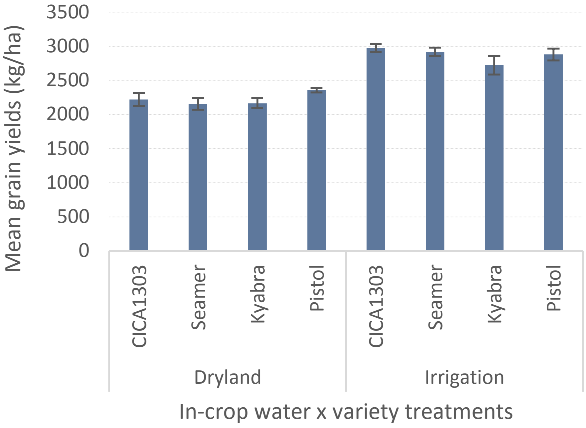


Figure 1. Variety yield performance across dryland and irrigated treatments

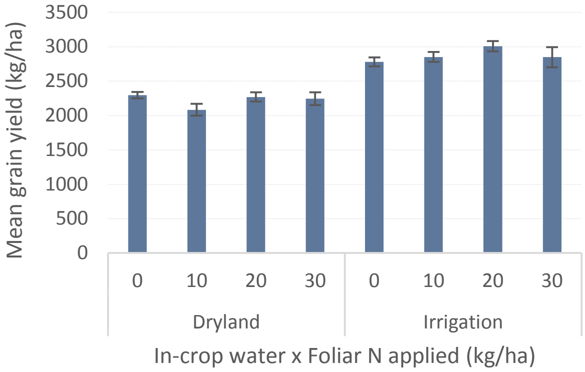


Figure 2. Response to foliar N applications across dryland and irrigation treatments

While the irrigated crop could compensate for the warmer temperatures it still did not perform as well the as crops planted a month earlier (nearly 12% difference) which would indicate that the late season weather pattern is still having an impact on crop performance.

Dry matter production followed a similar pattern to the grain yield data. There were no significant differences across varieties or the applied foliar nitrogen (N) treatments (Figure 4). Although there was an average difference in dry matter yield of 970 kg/ha between the irrigated treatment and the dryland treatments; this difference was not significant given the large variability in the individual plot data.

Figure 3. Maximum and minimum temperature records across the growing season

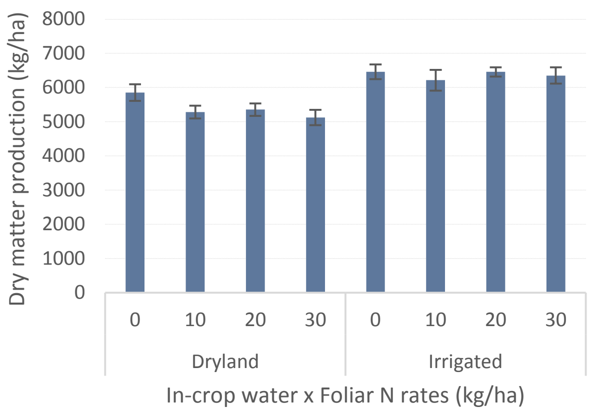


Figure 4. Mean dry matter yields for foliar N treatments across irrigated and dryland variables

Consequently harvest index data (Figure 5) was also not significant across varieties and foliar N treatments. There irrigated treatments on average had a higher harvest index (0.456 to 0.416), however this was not significant.

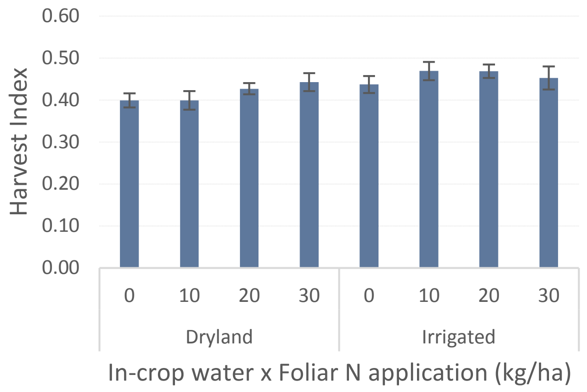


Figure 5. Mean harvest index values for foliar N treatments across irrigated and dryland variables

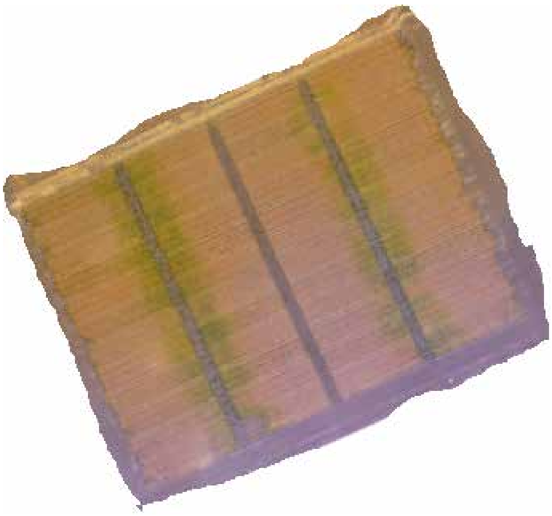
Table 1. Individual plant mapping data

	Seed number	Seed weight (g)	Total pods
Irrigated	66.5	15.5	56
Dryland	50.5	10.6	47
Difference	16	4.9	9
LSD (P=5%)	11.02	2.88	8.45
Significance	*	**	*

*significant difference at 5% level, **highly significant at 1% level.

While dry matter production was not significantly different across the irrigated and dryland treatments the leaf area index data (Figure 6) does show the impact of additional moisture after flowering.

The trial reached nearly 90% leaf area index (LAI) by the start of flowering across all treatments. Four weeks after the first flower, LAI reduced to an average of 0.69 across the dryland treatments while the irrigated treatments were still averaging 0.89. This is a significant difference (Fpr=0.01) and demonstrates the amount of leaf mortality that occurred in the dry land treatments just four weeks after first flower. The first irrigation was applied at first flower and then a second irrigation was applied three weeks later; this provided the plant with enough moisture to maintain full canopy cover during a period of increasing temperatures. This in turn allowed the plant to intercept light for longer and contributed to filling more grain.



Drone image of trial site showing difference in maturity between irrigated strips and dryland strips

Individual plant mapping data (Table 1) shows how the yield differences between the irrigated and dryland plots were achieved. There was a significant difference between the average seed number per plant (32%) which was significant at the 5% level. There was also significant differences in the averages per plant for seed weight (46%) and pod number (19%).

Overall the extra water allowed the plant more time to not only set more pods and therefore more grain but also it increase the grain weight. Maintaining LAI index for longer and having the extra water available means more flowers went through to pods rather than being aborted and the early pods got time to increase their seed weight.

There were no real differences in the performance of the varieties across the trial in either yield, dry matter or harvest index. The biggest difference between varieties was in the days to flowering (Table 2), with PBA Pistol$^{\phi}$ becoming much quicker (45 days) in comparison to the other three varieties which averaged around 59 days. PBA Pistol$^{\phi}$ seems to be the only variety that has physiologically reacted to

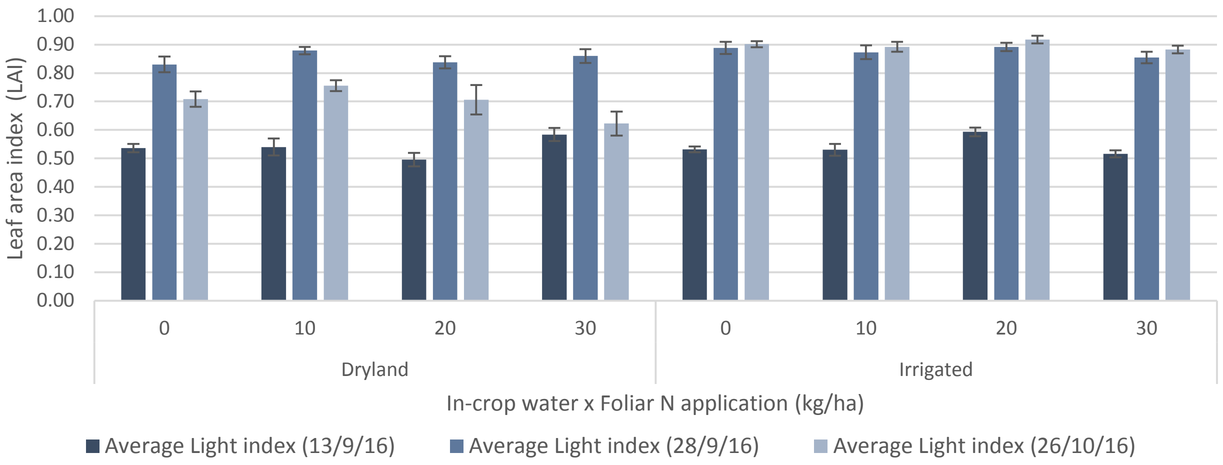


Figure 6. Average leaf area index values measured at; two weeks before flower (13/9/16), at flowering (28/9/16) and four weeks after flower (26/10/16)

the later sowing time by speeding up the time it takes to first flower (52 days planted one month earlier). However it did not change its vegetative growth rate, as its rate of canopy development (measured by LAI) was very similar to the other varieties.

Table 2. Summary of days to first flower across all treatments

Variety	Days to First Flower
CICA1303	60
PBA Seamerᶲ	59
Kyabraᶲ	59
PBA Pistolᶲ	45

Treatment plots 4 m wide with 2 m buffer either side on 1 m rows—dryland PBA Seamerᶲ plot in foreground, irrigated PBA Seamerᶲ in background

Implications for growers

Chickpeas is a crop that has a much wider adaptation to late season conditions than cereals, such as wheat and barley. This trial data has shown some evidence that the plant can continue to set pods and fill grain in increasing daily temperatures if there is adequate soil moisture available. Generally the plant sets more flowers than it can fill and then aborts whatever it cannot maintain. This allows the plant to set up for a bigger potential yield and then lets conditions dictate eventual yield.

Current varieties seem to be well adapted to late planting as there were no major differences in grain yield and all varieties took advantage of the supplementary irrigations.

Foliar nitrogen does not give any advantage to late season planted chickpeas, although the application timings were targeted to the flowering stage of the crop and not the vegetative stage of the life cycle.

Acknowledgements

The Queensland Pulse Agronomy Initiative (UQ00063) 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: Queensland Agricultural Training College, Emerald

Crop: Chickpeas (Kyabraᶲ, PBA Seamerᶲ, PBA Pistolᶲ, CICA1303)

Soil type: Black /Grey cracking Vertosol

2016 in-crop rainfall (mm):

Jun	Jul	Aug	Sep	Oct	Nov
73	83	16	33	13	15

Fertiliser: Supreme Z® at planting (30 kg/ha)

Selected soil fertility characteristics:

Depth (cm)	Nitrate N	Colwell P	S (KCl-40)	Exc. K	BSES P	CEC
0-10	21	51	8	0.81	91	33
10-30	17	14	9	0.40	33	33
30-60	11	4	11	0.32	17	34

Chickpea: impact of row spacing, plant population, variety and time of sowing on canopy development—Warwick

Kerry McKenzie and Jayne Gentry
Department of Agriculture and Fisheries

Research Question: *How does changing row spacing, plant population, variety and time of sowing impact on canopy development and water-use, and do these drive chickpea yield?*

Key findings

1. Cool conditions caused late pod set resulting in the first time of sowing growing a large biomass and flowering but not retaining pods until the same point in the season as the second time of sowing.
2. Yield and harvest index were greatest in the later time of sowing.
3. There were no major differences seen in water-use patterns due to the wet season.

Background

Previous chickpea trials have identified under various climatic conditions that harvest index (HI) has been inconsistent. Total dry matters and yields have been maximised when row spacings are reduced to 50 cm or below, while plant population has less influence when more than 20 plants/m² are established.

To gain a better understanding of the factors driving yield, namely canopy development, phenology, and water use, trials were designed to drive differences in plant development by altering plant population, row spacing, time of sowing and variety.

What was done

A trial was established in 2016 at the Department of Agriculture and Fisheries Hermitage Research Station (Warwick) in Queensland. This trial consisted of the following treatments:

- Two times of sowing (TOS): mid-June and mid-July
- Three cultivars: PBA HatTrick⏀, Kyabra⏀, PBA Seamer⏀
- Two row spacings: 50 cm and 75 cm
- Two populations: 15 and 30 plants/m²

The trial was planted using a seven row disc seeder with 25 cm row spacing. For 50 cm row spacing four rows were planted and for 75 cm three rows. Total dry matter (TDM) cuts were taken just prior to maturity. Grain was harvested using a plot harvester.

Access tubes were installed to allow soil moisture measurements with a neutron moisture meter in PBA HatTrick⏀ plots with a targeted population of 30 plants/m². Two access tubes were installed per plot, the first in the planted row and the second half way between rows in the interrow space. Neutron probe readings were taken at 20 cm depths throughout the growing season.

Results

The 2016 winter season saw late planting rains, a very wet spring, and cool temperatures that delayed pod set and maturity. In-crop rainfall to 19 December when the crop was ready for harvest was 479 mm for TOS 1 and 379 mm for TOS 2. However, final harvest was not conducted until 19 January 2017 due to continued rainfall (of approximately 150 mm).

Total dry matter production peaked at 15,635 kg/ha for PBA Seamer⏀ planted TOS 1 on 50 cm rows. The lowest TDM of 10,060 kg/ha was PBA HatTrick⏀ planted TOS 2 on 75 cm rows. Overall dry matter production was highest in TOS 1 at 50 cm and lowest in 75 cm for TOS 2. TOS 1 gave the highest TDM yields at both row spacings.

Harvesting was difficult due to crop lodging caused by late rainfall pushing the harvest back to January. Highest grain yields were achieved in TOS 2 for both row spacings (Figure 1) which had the lowest TDM.

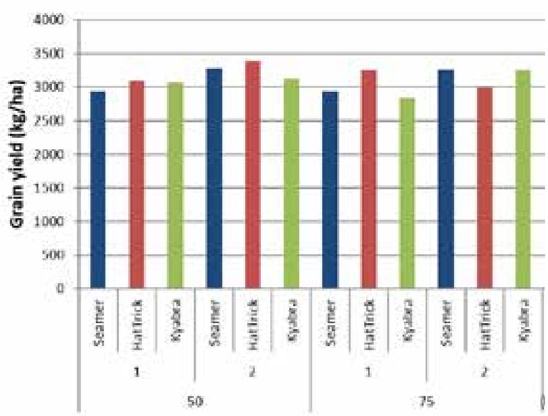


Figure 1. Chickpea grain yield at Hermitage at 50 cm and 75 cm row spacing and two times of sowing

Harvest index results were generally lower than expected of chickpeas with a site average of 0.26 (Figure 2). However the HI of TOS 2 were at or above this average, with 75 cm rows averaging 0.31.

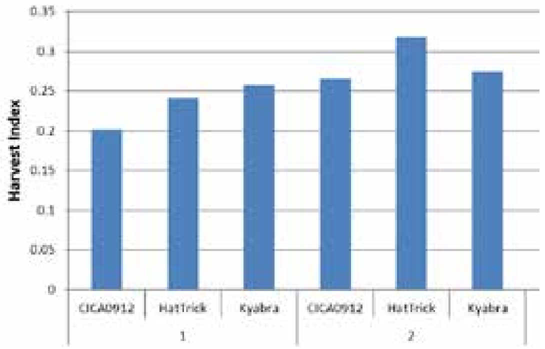


Figure 2. Hermitage Harvest Index figures influenced by variety and Time of Sowing

Cool temperatures in September restricted pod set. While TOS 1 flowered much earlier than TOS 2, pod set for both was at a similar time. Meaning TOS 2 did not accumulate as much biomass prior to pod set.

Water use was measured using neutron probes throughout the season. However due to the wet season very little difference in water use patterns were detected. Some results of note were; due to the wet spring very little soil moisture was utilised by chickpeas up until 7 October 2016. Water extraction accelerated in late October after the last major fall of rain with soil water decreasing at all depths to 125 cm. This also coincided with peak plant demand due to pod fill and warmer temperatures.

Implications for growers

Delaying TOS improved the HI with less dry matter accumulated. The seasonal conditions led to very high biomass accumulation with flowering delayed until October. The late flowering and length of pod fill time meant HI were below expectation and yields did not reflect the large biomasses.

Seasonal conditions such as the high in-crop rain and delay to pod set until late in the year (when 15°C average temperatures were achieved) were responsible for lower yields and HIs. Future research is planned to try and manipulate the plant to convert high biomasses into yields.

Acknowledgements

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.

Trial details

Location:	Hermitage Research Station, Warwick
Crop:	Chickpea
Soil type:	Brown Vertosol
In-crop rainfall:	TOS 1 = 479 mm TOS 2 = 379 mm
Fertiliser:	50 kg/ha GreenfieldX®

Chickpea canopy trial, Hermitage Research Station

Nutrition research

Over the last three years the UQ00063 project (Regional Soil testing Guidelines) has been establishing and monitoring a series of nutrition experimental sites across Queensland and northern New South Wales. These trial sites were chosen based on soil testing evidence showing varying degrees of nutrient depletion in the surface and subsurface layers. This is particularly evident in the non-mobile nutrients of phosphorus (P) and potassium (K). In some established zero tillage production systems there is a marked difference between the nutrient concentration in the top 10cm of the soil profile and the deeper layers (10-30 cm and 30-60 cm) that cannot be explained by natural stratification.

Current trials are determining whether the one off application of either P, K and/or sulfur (S) that is deeper placed in the soil (20 cm) can provide a grain yield benefit and whether that benefit can be maintained over several years. These results can also be used to define the economic benefit of adding these non-mobile nutrients over successive cropping cycles.

The 2016 winter and summer seasons have shown some conflicting results across nutrition trial sites. Sorghum crops planted on several trial sites have shown up to a 25% response in grain yield to deep P applications in both southern (Lundavra and Jimbour West) and central Queensland (Clermont and Dysart). Some of these sites were on their third crop since treatments were first applied which is starting to demonstrate the longevity of P and K applications.

The winter crop results have been less emphatic with few significant responses recorded in both chickpea and wheat plantings across Queensland. The main difference between these two cropping seasons has been the amount and spread of in-crop rainfall.

The summer of 2016 proved to be challenging with hot and dry conditions extending over much of the state and this in turn dried out surface profiles and put pressure on summer crops to live off stored soil moisture. The winter of 2016 was the complete opposite where in most areas there was record breaking rainfall events throughout July, August and September.

This has proved to have a large impact on responses to deep placed nutrition trials. Winter crops were able to access nutrients in the top 10 cm of the soil profile for long periods of time while they were wet and consequently there was little extraction from the deep placed bands of P and K. There is evidence provided by dry matter analysis that the plants had access to the deep bands of fertiliser but this was surplus to requirements as increased uptake did not result in increased yields.

Once again responses to sulfur have been elusive across all trial sites for the 2016 crops and this highlights that our understanding of this macro nutrient in our cropping system requires improvement and further research.

Sorghum: responsive to deep-applied phosphorus, potassium and sulfur in open downs soils—Clermont

Doug Sands and Dr David Lester

Department of Agriculture and Fisheries

Research Question: *Does the deep application of phosphorus, potassium and sulfur increase sorghum yields in a soil with marginal soil test values?*

Key findings

1. Deep-applied phosphorus improved grain yields by up to 30%.
2. Starter phosphorus improved grain yield by 8%.
3. Deep-applied potassium improved grain yield by 10%.
4. No response to deep-applied sulfur.

Background

Over the last three years the UQ00063 project (Regional Soil testing Guidelines) has been establishing and monitoring a series of nutrition experiment sites across Central Queensland (CQ). These trial sites were chosen based on soil testing evidence showing varying degrees of nutrient depletion in the surface and sub-surface layers. This is particularly evident in the non-mobile nutrients of phosphorus (P) and potassium (K). In some established zero tillage production systems there is a marked difference between the nutrient concentration in the top 10 cm of the soil profile and the deeper layers (10-30 cm and 30-60 cm) that cannot be explained by natural stratification. It would seem that this pattern of soil analysis is becoming more evident across CQ; particularly in the brigalow scrub and open downs soil types.

This project is determining whether the one off application of either P, K and/or sulfur (S) that is deeper placed in the soil (20 cm) can provide a grain yield benefit and whether that benefit can be maintained over several years. These results can also be used to define the economic benefit of adding these non-mobile nutrients over successive cropping cycles.

What was done

This trial site was established in October 2015 and then planted to sorghum in February 2016, consequently this trial report is the first set of cropping data from this site. Based on the information contained in the original soil characterisation tests (see Trial details) it was decided to locate three individual rate response trials at this site: one each for P, K and S.

Phosphorus trial (P)

There were eight treatments in total (Table 1a), which included 4 P rates; 0, 10, 20, and 40 kg P/ha (0P, 10P, 20P and 40P). All treatments had background fertiliser applied at the same time to negate any other limiting nutrients. This basal fertiliser was 80 kg nitrogen (N), 50 kg K, 20 kg sulfur (S) and 1 kg zinc (Zn) per hectare. Two contrasting treatments included 0P and 40P without any background K and S fertiliser (0P-KS, 40P-KS) to assess the impact of P only. The last two treatments were, a farmer reference (FR) plot and an extra 0P plot; to give two controls for each replicate. The FR treatments had nothing applied except what the farmer applies in line with normal commercial practice, benchmarking current production levels. Various commercial fertiliser products were used to make up the treatments (Table 2).

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 fertiliser bands were placed 50 cm apart in plots that were 8 m wide by 32 m long and in the same direction as the crop rows. Additionally this trial also had another variable applied at planting. Each deep applied treatment had three different rates of starter P (Granulock Supreme Z®) applied at planting with seed; these included a zero rate (control), 15 kg/ha and 30 kg/ha.

The three starter P treatments across the eight deep P treatments meant that each of the six replicates had 24 plots, for a total of 144 plots for the trial.

Sorghum (Pioneer hybrid G33®) was planted into the P trial with a 2 m plot planter on 16 February 2016 and harvested on 5 August. The crop was planted on 1.5 m rows into good soil moisture and received moderate in-crop rainfall (see Trial details).

Table 1a. Summary of nutrient application rates for the phosphorus trial

Treatment label		Nutrient rate (kg/ha)					
Main	Starter	N	Starter P	P	K	S	Zn
0P	No St	80	0	0	50	20	2
0P	St	80	3	0	50	20	2
0P	Stx2	80	6	0	50	20	2
0P	No St	80	0	0	50	20	2
0P	St	80	3	0	50	20	2
0P	Stx2	80	6	0	50	20	2
10P	No St	80	0	10	50	20	2
10P	St	80	3	10	50	20	2
10P	Stx2	80	6	10	50	20	2
20P	No St	80	0	20	50	20	2
20P	St	80	3	20	50	20	2
20P	Stx2	80	6	20	50	20	2
40P	No St	80	0	40	50	20	2
40P	St	80	3	40	50	20	2
40P	Stx2	80	6	40	50	20	2
40P-KS	No St	80	0	40	0	0	2
40P-KS	St	80	3	40	0	0	2
40P-KS	Stx2	80	6	40	0	0	2
0P -KS	No St	80	0	0	0	0	2
0P -KS	St	80	3	0	0	0	2
0P -KS	Stx2	80	6	0	0	0	2
FR	No St	0	0	0	0	0	0
FR	St	0	3	0	0	0	0
FR	Stx2	0	6	0	0	0	0

Potassium trial (K)

The potassium experiment is exploring application of K with/without P and S being present. There were eight treatments including 4 K rates: 0, 25, 50, and 100 kg K/ha with a background fertiliser of 80 kg N, 20 kg P, 20 kg S and 1 kg Zn per hectare. Contrasting this are two treatments 0K and 100K without PS fertiliser (0K-PS, 100K-PS). Remaining treatments were a farmer reference (FR) and an extra 0K to give two controls in each replicate. The FR plots were not treated with anything except what the farmer applies in line with normal commercial practice.

Applications were done in the same way as the P trial (Table 1b). The K trial was planted with the farmers 24 m zero till planter on 1.5 m row spacing and a blanket rate of starter P as a liquid injection (Hydrofert Beta® 15 L/ha plus Awaken® 1 L/ha) was applied to the whole trial with the seed at planting. Urea was also applied at planting; in between the plant rows at a rate of 80 kg/ha. Plot dimensions were the same as the P trial however there were eight deep applied treatments in each of the six replicates giving a total of 48 plots for the trial.

Table 1b. Summary of nutrient application rates for the potassium trial

Main treatment label	N rate (kg/ha)	P rate (kg/ha)	K rate (kg/ha)	S rate (kg/ha)	Zn rate (kg/ha)
0K	80	20	0	20	2
0K	80	20	0	20	2
25K	80	20	25	20	2
50K	80	20	50	20	2
100K	80	20	100	20	2
0K-PS	80	0	0	0	2
100K-PS	80	0	100	0	2
FR	0	0	0	0	0

Sulfur trial (S)

There were eight treatments in total which included 4 S rates; 0, 10, 20, 30kg 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, 20 kg P, 50 kg K and 1 kg Zn per hectare.

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 (FR) treatment. Treatments were applied in the same way as both the P and K trials (Table 1c). This trial was planted by the farmer co-operator in the same way as the K trial.

Table 1c. Summary of nutrient application rates for the sulfur trial

Main treatment label	N rate (kg/ha)	P rate (kg/ha)	K rate (kg/ha)	S rate (kg/ha)	Zn rate (kg/ha)
0S	80	20	50	0	2
0S	80	20	50	0	2
10S	80	20	50	10	2
20S	80	20	50	20	2
30S	80	20	50	30	2
0S-PK	80	0	0	0	2
30S-PK	80	0	0	30	2
FR	0	0	0	0	0

Table 2. 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%)
Sulfur (S)	GranAm (24%)
Zinc (Zn)	Agrichem Supa zinc (Liq) (7.5%w/v)

Data collection was done the same way for all three trials. Plant counts, starting soil water and starting nitrogen (N) measurements were taken post emergence. Total dry matter measurements were taken at physiological maturity and yield measurements were taken with a plot harvester when commercial harvesting started in the same paddock. Two harvest samples were taken from each plot and a grain sample was kept from the plot for nutrient analysis. Both the dry matter samples and the grain samples were ground down and subsampled for a wet chemistry analysis.

Results

Phosphorus trial

There is clearly a significant increase to both the deep applied P bands as well as the starter P application (Table 3b). There also seems to be a rate response with the higher rate of 40P giving an almost another 20% improvement in yield over the 10P and 20P rates. Overall there is an almost 40% increase in yield in response to deep applied P. The size of the response is larger than previous trial data has suggested however this could be due to the fact that the crop had only 66 mm total in-crop rainfall and this fell in the first five weeks after planting. Therefore the plant would not have had any access to the top 10 cm of the soil profile during flowering and grain fill.

Table 3a. Comparison of mean grain yields across deep placement treatments in phosphorus trial

Treatment	Mean grain yield (kg/ha)		Relative yield difference to '0P' plots kg/ha	%
FR	1628	a	-314	-16.2
0P-KS	1971	b	29	1.5
0P	1942	b	0	0.0
10P	2371	c	429	22.1
20P	2317	c	375	19.3
40P	2701	d	760	39.1
40P-KS	2636	d	695	35.8

#Least significant difference test (5% level). Means without a common letter are significantly different (l.s.d = 168)

This trial has also given an 8% response to starter P although there was no response to the rate of starter P applied nor was there any significant interaction between the starter P and the deep applied P treatments. This means the response to Starter P was uniform across all deep P treatments. When the data is averaged across all plots including the FR plots (Table 3b) the yields indicate the response to starter P was most likely driven by root access rather than soil concentration as the higher rate of starter P did not increase the response. It was more important that the seedling had some access to applied P while its root system was still small and underdeveloped and therefore the total amount of P was not important. The early access to starter P may also contribute to the determination of grain number at floral initiation as this would have occurred in the first six weeks of crop development.

Table 3b. Comparison of mean grain yields across surface applied starter P treatments at planting

Treatment	Mean grain yield (kg/ha)		Relative yield difference to 'no St' plots kg/ha	%
No St	2057	a	0	0.0
St	2239	b	182	8.1
St x2	2269	b	212	9.4

#Least significant difference test (5% level). Means without a common letter are significantly different (l.s.d = 123)

Visual response to the P treatments were most evident at early flowering stages. The pictures show the delay in flowering from plots that had either no starter P and/or no deep P applied.

Plot in foreground is a 0P treatment, plot in background is a 40P treatment

Plot in foreground is a 0P with no starter treatment, plot in background is a 0P with double starter treatment

Potassium trial

Table 4. Comparison of mean grain yields across deep placed potassium treatments

Treatment	Mean grain yield (kg/ha)		Relative yield difference to '0K' plots	
			kg/ha	%
FR	1872	a	-772	-29%
0K-PS	2233	b	-411	-16%
0K	2644	c	0	0%
25K	2678	cd	34	1%
50K	2878	de	234	9%
100K	2932	e	288	11%
100K-PS	2184	b	-461	-17%

#Least significant difference test (5% level). Means without a common letter are significantly different (l.s.d = 224)

Grain yield results (Table 4) demonstrate a significant yield difference for the two highest rates of potassium however this only represents a 9-11% improvement in yield as opposed to the 20-40% increase that was achieved with phosphorus. This highlights the fact that P is the most limiting factor in this site for this crop, but once P has been satisfied then K is the next limiting factor. This is reinforced by the results in treatments where the P has been left out (0K-PS, 100K-PS) having a yield decline of between 16-17% compared to the 0K treatment which has P applied.

Soil test results for this site would also indicate that K should be less limiting than P. Sub-surface K levels of 0.2–0.25 meq/100 g are thought to be only just marginal where as Colwel P levels of 2 mg/kg or less, are judged to be highly deficient. Soil analysis for this site also indicates that K levels in the surface (0-10 cm) are between 0.4 to 0.8 meq/100g which should be non-limiting. The fact that a small significant response was obtained from deep K placement demonstrates how little access the plant had to surface nutrients during the crops lifecycle.

The farmer reference plots (FR) have once again been the lowest yielding by up to 40%. The difference between the FR and the 0K-PS (13%) would suggest that the site is limited also by nitrogen or compaction given the only difference between the two treatments is 80 kg/ha of nitrogen (N) and the ripping associated with the application of N. This site has been under controlled traffic management for a number of years so compaction should not be an issue; therefore N may be the more limiting factor for this site.

Sulfur trial

Table 5. Comparison of mean grain yields across deep placed sulfur treatments

Treatment	Mean grain yield (kg/ha)		Relative yield difference to '0S' plots	
			kg/ha	%
FR	1835	a	-921	-33%
0S-PK	2160	b	-596	-22%
0S	2756	c	0	0%
10S	2708	c	-48	-2%
20S	2770	c	13	0%
30S	2720	c	-36	-1%
30S-PK	2272	b	-484	-18%

#Least significant difference test (5% level). Means without a common letter are significantly different (l.s.d. = 213)

There was no significant difference between any of the additional sulfur applications (Table 5) despite soil analysis indicating that sulfur throughout the top 60 cm of the profile was less than 3 mg/kg (see trial details). This has been a common occurrence in trial sites where P and K have proven to be most limiting.

The results from this sulfur trial reinforces the fact that P has been the most limiting nutrient as the treatments without background P, have had reduced yields of between 18-22%. The FR treatments have been the lowest yielding with an average difference of 11% when compared to the 0S-PK plots. This is similar to the result in the K trial which emphasises the difference that additional nitrogen or ripping can make.

Implications for growers

The depletion of phosphorus in the soil profile can have major consequences on grain yields in sorghum. This trial has demonstrated a yield increase of between 20-40% across deep P treatments of which some of this could be attributed to a response to surface applied P of 8-9%. Soil test values show P to be below 5 mg/kg both in the top soil (0-10 cm) and in the subsequent layers (10-30 cm, 30-60 cm) and this has proven to be a major limiting factor to grain production. In some situations where nutrient stratification is apparent, P levels are much higher in the surface soil then the subsurface layers and this can reduce the response to deep P if there is enough in-crop rainfall for the plant to access surface nutrients. However when both surface and subsurface layers are deficient then a large response to deep P is more predictable.

Potassium does have the potential to limit yields if critical levels in the subsurface (10-30 cm) have been reached. In this trial site a small response (10%) was recorded with high rates of K, however this only occurred if background P was also present. Soil tests levels show that K was not highly deficient in this site so a large response from K was not expected. Both K and P are immobile nutrients in the soil so when nutrient stratification occurs then it is not unusual to see K being depleted in the sub-surface layers at the same time as P.

In this case P has been the most limiting nutrient but once this has been rectified then K has also given a small response. There results have occurred in the first crop after application, whether these results will continue to be replicated in subsequent crops will need to be tested through further monitoring.

Sulfur responses seem to be limited in sites that have another major limiting nutrient such as N, P or K; even when soil analysis would suggest that sulfur is also limited. At this stage there is no clear explanation why this should occur and further research is required to explore this problem.

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 UQ 00063 'Regional soil testing guidelines for the northern grains region'.

Trial details

Location:	Clermont
Crop:	Sorghum (Pioneer hybrid G33®)
Soil type:	Dark Grey Vertosol (open downs with basalt strata) on minor slopes
In-crop rainfall:	66 mm
Fertiliser:	80 kg/ha of urea at planting between the rows 15 L/ha of Hydrofert Beta® plus 1 L/ha of Awaken® at planting with the seed

Selected soil fertility characteristics for the trial site:

Depth	Nitrate Nitrogen	Phosphorus Colwell	BSES Phosphorus	PBI	Exc. Potassium	Sulfur (KCl-40)	ECEC
cm	mg/Kg	mg/Kg	mg/Kg		meq/100g	mg/Kg	meq/100g
0-10	4	5	38	152	0.48	2.4	61.4
10-30	10	2	26	157	0.22	2.7	64.7
30-60	6	< 2	61	167	0.18	2.1	65.1

Wheat: residual effect of deep placed phosphorus—Bauhinia and Emerald

Doug Sands and Dr David Lester

Department of Agriculture and Fisheries

Research Question: *Does the deep application of phosphorus increase wheat yields two years after application?*

Key findings

1. Variable response to residual deep applied phosphorus depending on site (0 to 10%).
2. Shortage of nitrogen may be causing interference in phosphorus uptake.
3. In-crop rainfall impacts on response to deep applied phosphorus.

Background

Over the last three years the UQ00063 project (Regional Soil testing Guidelines) has been establishing and monitoring a series of nutrition experimental sites across Central Queensland (CQ). These trial sites were chosen based on soil testing evidence showing varying degrees of nutrient depletion in the surface and sub-surface layers. This is particularly evident in the non-mobile nutrients of phosphorus (P) and potassium (K). In some established zero tillage production systems there is a marked difference between the nutrient concentration in the top 10 cm of the soil profile and the deeper layers (10-30 cm and 30-60 cm) that cannot be explained by natural stratification. It would seem that this pattern of soil analysis is becoming more evident across CQ; particularly in the brigalow scrub and open downs soil types.

This project is determining whether the one off application of either P, K and/or sulfur (S) that is placed in the depleted subsurface layer (20 cm) can provide a grain yield benefit and whether that benefit can be maintained over several years. These results can also be used to define the economic benefit of a once off application over successive cropping cycles.

What was done

This report will cover two similar phosphorus (P) trials that were established in 2015. One site was established near Bauhinia (west of Moura) in early March and the other site was set up at the Queensland Agricultural Training

Table 1. Summary of nutrient application rates for the phosphorus trial

Main treatment	Starter treatment	N rate (kg/ha)	Starter P rate (kg/ha)	P rate (kg/ha)	K rate (kg/ha)	S rate (kg/ha)	Zn rate (kg/ha)
0P	Nil starter	80	0	0	50	20	2
0P	Starter	80	6	0	50	20	2
10P	Nil starter	80	0	10	50	20	2
10P	Starter	80	6	10	50	20	2
20P	Nil starter	80	0	20	50	20	2
20P	Starter	80	6	20	50	20	2
40P	Nil starter	80	0	40	50	20	2
40P	Starter	80	6	40	50	20	2
40P-KS	Nil starter	80	0	40	0	0	2
40P-KS	Starter	80	6	40	0	0	2
0P -KS	Nil starter	80	0	0	0	0	2
0P -KS	Starter	80	6	0	0	0	2
FR	Nil starter	0	0	0	0	0	0
FR	Starter	0	6	0	0	0	0

College (QATC), Emerald in early January. Both these sites had soil tests that indicated limited amounts of P at depth but with reasonable surface (0-10 cm) P levels (see Trial details for soil analysis). For both trial sites the 2016 wheat crop was the second crop harvested since the initial fertiliser treatments had been applied.

There were eight treatments in total (Table 1), which included 4 P rates; 0, 10, 20, and 40 kg P/ha (0P, 10P, 20P and 40P). All treatments had background fertiliser applied at the same time to negate any other limiting nutrients. This basal fertiliser was 80 kg nitrogen (N)/ha, 50kg K/ha, 20kg sulfur (S)/ha and 1 kg zinc (Zn)/ha. Two contrasting treatments included 0P and 40P without any background K and S fertiliser (0P-KS, 40P-KS) to assess the impact of P only. The last two treatments were, a farmer reference (FR) plot and an extra 0P plot; to give two controls for each replicate. The FR treatments had nothing applied except what the farmer applies in line with normal commercial practice, benchmarking current production levels. The QATC trial had an extra FR plot added per replicate to help fit the trial design into the area allocated. Table 2 lists the commercial fertiliser products that were used to make up 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 fertiliser bands were placed 50 cm apart in plots that were 6 m wide by 32 m long and in the same direction as the old stubble rows.

The Bauhinia trial was managed by the co-operator and the QATC trial was managed by the research team. This means the Bauhinia trial was planted with existing commercial 18 metre zero till tyned planter, whereas the QATC trial was planted with a two metre tyned plot planter.

Additionally the QATC trial site had another variable applied at planting. Each deep applied treatment had 'with' and 'without' starter P (Granulock Supreme Z®) applied at planting with seed. The 'with' treatment was applied at a rate of 30 kg/ha. The Bauhinia trial had no starter P treatments applied for this crop so each of the six replicates had 8 plots, for a total of 48 plots for the site. The QATC trial had 18 plots per replicate but only four replicates used giving a total of 72 plots for the site.

The Bauhinia site was planted on 9 June 2016 with Gregory wheat at 45 kg/ha on 40 cm rows. The QATC site was planted on 16 May 2016 also with Gregory wheat at 50 kg/ha on 50 cm rows. Bauhinia was harvested on the 27 October and QATC was harvested on the 17 October. The QATC site had 210 mm of in-crop rainfall and Bauhinia had 243 mm (see trial details).

Table 2. 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%)
Sulfur (S)	GranAm (24%)
Zinc (Zn)	Agrichem Supa zinc (Liq) (7.5%w/v)

For both trials the collection of data was done in the same way. Plant counts, starting soil water and starting nitrogen (N) measurements were taken post emergence. Total dry matter measurements were taken at physiological maturity and yield measurements were taken with a plot harvester when commercial harvesting started in the same paddock. One harvest sample was taken from each plot and a grain sample was kept from the plot for nutrient analysis. Both the dry matter samples and the grain samples were ground down and subsampled for a wet chemistry analysis.

Results

The results from the two trial sites are quite different so they are presented as two separate sections.

Bauhinia trial

The Bauhinia trial site had a small response to the residual deep P treatments. Both the 20P and 40P rates have given a positive but modest response in grain yield against the 0P rate (Table 3). Dropping the background K and S nutrition has not produced any change in grain yield which shows that this site does not have any limitations to K and S nutrition. This was expected as the soil test analysis showed that K and S should not be limiting (see trial details).

The modest response in this trial could be at least partially attributed to seasonal influences with the crop benefiting from good in-crop rainfall (243 mm) spread across the first three months of the crops life (see Trial details). This site had good levels of P in the surface layer (0-10 cm) and the in-crop rainfall would have made it possible for the plant roots to access most of this surface nutrition. Protein levels for all treatments were between 12.9% and 13.4% (Table 3), which means that nitrogen was not limiting the uptake of the other elements.

Table 3. Mean grain yields comparison for Bauhinia trial site

	Mean grain yield	LSD	Relative difference to '0P' plots		Mean protein
	(kg/ha)	(P=5%)	(kg/ha)	(%)	(%)
FR	3437	ab	101	3.0	12.9
0P-KS	3394	a	58	1.7	13.7
0P	3336	a	0	0.0	13.1
10P	3468	abc	132	4.0	13.2
20P	3625	bc	289	8.6	13.3
40P	3667	c	331	9.9	13.1
40P-KS	3508	abc	171	5.1	13.4

Means with the same letter are not significantly different (l.s.d=205)

Dry matter production followed a similar trend to grain yields, with the highest rate of deep P showing a significant increase in biomass produced (950 kg/ha) against the OP plots (Figure 1). However considerable variability between replicates in those treatments without any P (possibly reflecting variable P reserves or access to topsoil layers) made it difficult to demonstrate a consistent rate response across the site. There was no significant response in harvest index as grain yield and dry matter followed a similar pattern.

Small visual differences in dry matter at mid-tillering (FR plot foreground, 20P background)

Emerald trial

The QATC site showed a significant response to deep tillage and possibly some residual basal N from year 1 (0P-KS ›FR), and an additive effect of applying background nutrients (0P › 0P-KS). However there was no additional yield benefit from any rate of deep P applied in year one, nor was there any response to applications of starter P (data not shown). The lack of deep P response was surprising, as the soil analysis showing a Colwell P of 6 mg/kg in the 10-30 cm layer suggested the site should be P-responsive, while the soil test also suggested K and S were in adequate supply.

Nitrogen supply could have been limited at this site, given the low average protein levels that were measured across all treatments (Table 4).

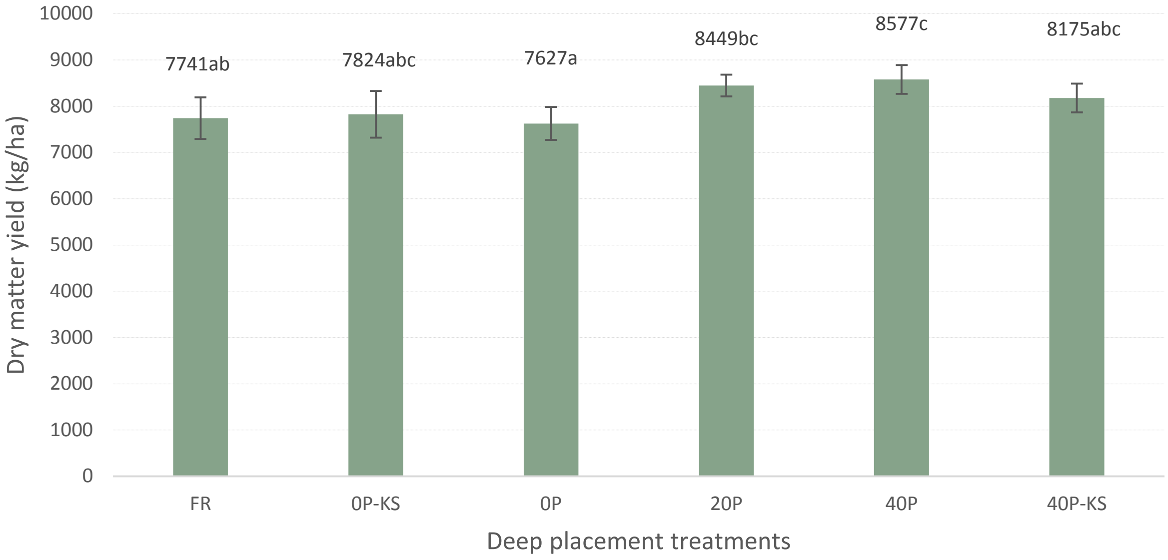


Figure 1. Comparison of dry matter yields across deep P treatments at Bauhinia site (l.s.d=782)

Table 4. Mean grain yield comparison for QATC trial site

	Mean grain yield	LSD	Relative difference to '0P' plots		Mean NIR protein
	(kg/ha)	(P=5%)	(kg/ha)	(%)	(%)
FR	3225	a	-382	-10.6	9.4
0P-KS	3443	b	-163	-4.5	10.0
0P	3607	c	0	0.0	9.6
10P	3703	c	96	2.7	10.2
20P	3552	bc	-55	-1.5	9.5
40P	3628	bc	21	0.6	9.5
40P-KS	3517	bc	-90	-2.5	9.6

Means with the same letter are not significantly different (l.s.d=188)

There were no significant differences in proteins between treatments, but a range of 9.4% to 10.2% would indicated that all treatments were lacking nitrogen. Previous research (Cox, H. and Strong, W. (2009) *The Nitrogen Book*) has established that protein levels below 11.5% indicate that nitrogen availability is less than that required to meet the seasonal yield potential, which was quite high in this wetter (210 mm) growing season. Total nitrate calculations down to a depth of 120 cm shows there was 84 kg N/ha available at planting and this is well short of the 120 kg N/ha that is theoretically required by a 3.5 t/ha wheat crop with a protein level of 11.5%. The lack of available N may have interfered with the plants ability to get full value out of the P treatments.

It is also worth noting that the 0-10 cm Colwell P at this site was quite high (30 mg/kg), and the significant in-crop rainfall for this site would have helped keep the surface roots active in the top 10 cm of the profile and allowed access to the surface pool of available P. When this occurs, responses to deep P applications are likely to be minimal.

There was no significant response in dry matter to either deep P or starter P applications (Figure 2), although on a visual assessment the FR plots looked to have much less dry matter than the other treatments. The variability in biomass data between replicates made achieving statistical significance more difficult at this site.

Only real visual differences in dry matter was in the FR plots (foreground). Background plot is 40P-KS

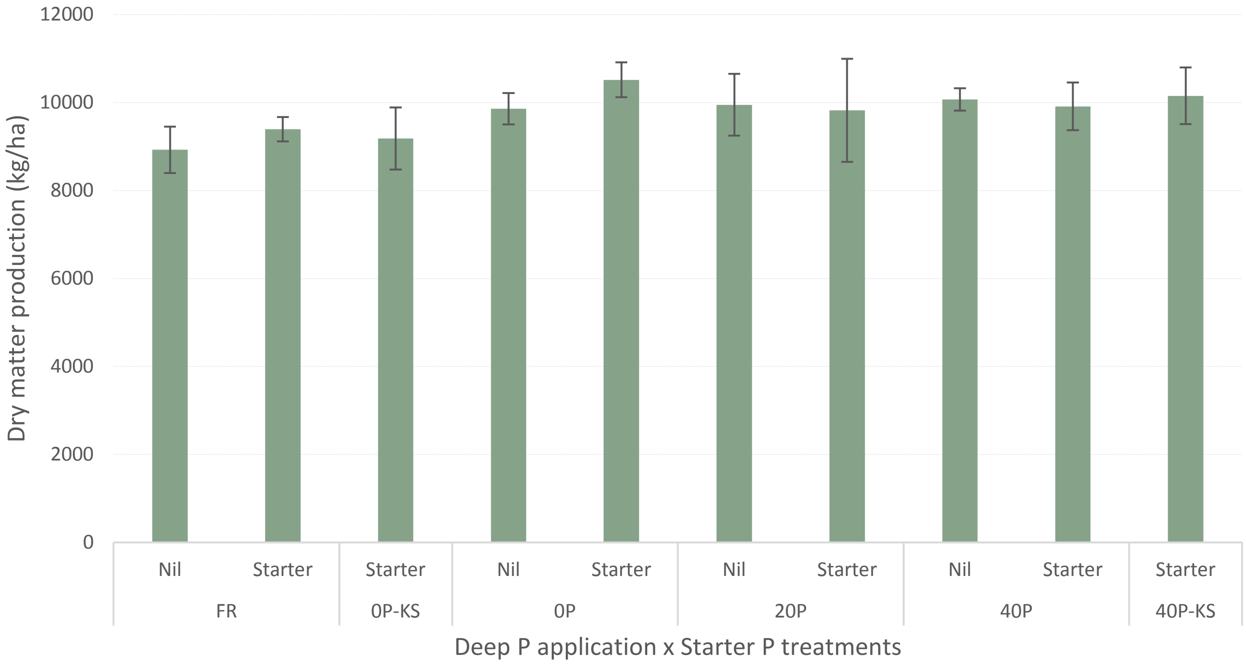


Figure 2. Comparison of dry matter production across all treatments at the Emerald site

Implications for growers

The performance of wheat across the two trial sites in 2016 has reinforced the fact that seasonal conditions play an important part in how the plant can access P. The 2016 season was highlighted by the extraordinary amounts of rainfall that occurred across July and August, which is a major anomaly in relation to average CQ winter seasons.

Soil profiles that have depleted subsurface P but have managed to maintained good levels of P in the surface soil, through the breakdown of stubble and the addition of Starter P, can provide adequate supplies of P to the plant as long as the roots can access those surface layers. This requires regular rainfall throughout the season to keep the soil wet, which is largely what happened in 2016 (see Trial details). The other advantage of winter rainfall is that the cooler temperatures reduce the level of evaporation so the surface soil stayed wetter for longer, which in turn increased the time that the surface roots of the plant have access to the P in the surface layers.

The other issue highlighted by this data is the importance of maintaining adequate nitrogen supply for the crop. Previous experiments have shown that limited nitrogen supply can have a big effect on the response to other nutrients, with cereal crops especially vulnerable. While grain protein can provide some indications as to where this has occurred in different trials, it does seriously limit the ability to quantify the residual responses to deep P bands. The QATC trial data has reinforced this characteristic, although the low N availability was a surprise given the residual N that should have carried forward from the previous crop season. Further investigations are required to find out what happened to the nitrogen that was applied in the initial treatments for this site.

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 UQ 00063 'Regional soil testing guidelines for the northern grains region'.

Trial details

Location: Bauhinia and Emerald
Crop: Wheat (Gregory$^{(D)}$)
Soil type: Brown and Grey Vertosol (mixed brigalow scrub) on minor slopes and plains
Monthly rainfall totals (mm):

	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16
Bauhinia		68	105	18	30	22
Emerald	0	73	83	16	33	13

Fertiliser: Bauhinia—100 kg/ha of urea applied pre-plant

Emerald—30 kg/ha of Supreme Z® applied in designated strips with seed at planting

Selected soil fertility characteristics for the Bauhinia trial site:

Depth (cm)	Nitrates	Colwell P	Sulfur (KCl-40)	Exc. K	BSES P	ECEC
0-10	1	12	2	0.85	36	31
10-30	1	3	3	0.5	19	33
30-60	<1	2	6	0.43	15	34

Selected soil fertility characteristics for the Emerald trial site:

Depth (cm)	Nitrates	Colwell P	Sulfur (KCl-40)	Exc. K	BSES P	ECEC
0-10	20	30	6	0.95	71	35
10-30	8	6	4	0.49	46	37
30-60	5	2	6	0.42	37	38

Wheat: not responsive to deep applied phosphorus and potassium on scrub soils—Dululu

Doug Sands and Dr David Lester

Department of Agriculture and Fisheries

RESEARCH QUESTION: *Does the deep application of phosphorus and potassium increase wheat yields in a soil with marginal soil test values?*

Key findings

1. No responses to deep applied phosphorus and potassium in a wet year.
2. No response to starter phospohorus.

Background

Over the last three years the UQ00063 project (Regional Soil Testing Guidelines) has been establishing and monitoring a series of nutrition experimental sites across Central Queensland (CQ). These trial sites were chosen based on soil testing evidence showing varying degrees of nutrient depletion in the surface and subsurface layers. This is particularly evident in the non-mobile nutrients of phosphorus (P) and potassium (K). In some established zero tillage production systems there is a marked difference between the nutrient concentration in the top 10 cm of the soil profile and the deeper layers (10-30 cm and 30-60 cm) that cannot be explained by natural stratification. It would seem that this pattern of soil analysis is becoming more evident across CQ; particularly in the brigalow scrub and open downs soil types.

This project is determining whether the one off application of either P, K and/or sulfur (S) that is placed in the depleted subsurface layer (20 cm) can provide a grain yield benefit and whether that benefit can be maintained over several years. These results can also be used to define the economic benefit of a once off application over successive cropping cycles.

What was done?

This trial site was established in November 2015 and then planted to wheat in early June 2016, consequently this trial report is the first set of cropping data from this site. Based on the information derived from the original soil characterisation tests (see Trial details) it was decided to locate two individual rate response trials at this site: one each for P and K.

Table 1a. Summary of nutrient application rates for the phosphorus trial

Main treatment	Starter treatment	N rate (kg/ha)	Starter P rate (kg/ha)	P rate (kg/ha)	K rate (kg/ha)	S rate (kg/ha)	Zn rate (kg/ha)
0P	Nil starter	80	0	0	50	20	2
0P	Starter	80	1.5	0	50	20	2
10P	Nil starter	80	0	10	50	20	2
10P	Starter	80	1.5	10	50	20	2
20P	Nil starter	80	0	20	50	20	2
20P	Starter	80	1.5	20	50	20	2
40P	Nil starter	80	0	40	50	20	2
40P	Starter	80	1.5	40	50	20	2
40P-KS	Nil starter	80	0	40	0	0	2
40P-KS	Starter	80	1.5	40	0	0	2
0P -KS	Nil starter	80	0	0	0	0	2
0P -KS	Starter	80	1.5	0	0	0	2
FR	Nil starter	0	0	0	0	0	0
FR	Starter	0	1.5	0	0	0	0

Phosphorus trial (P)

There were eight treatments in total (Table 1a). Each trial contained a farmer reference (FR) treatment and a 0P treatment, providing contrasting ‘controls’ in each replicate. The FR treatments had no deep tillage and only the nutrients applied by the co-operator in line with normal commercial practice, benchmarking current production levels. All other treatments were ripped, and had additional nitrogen (N) fertiliser applied (80 kg N/ha) to ensure N deficiency did not limit grain yield. A subset of the remaining treatments (0P-KS and 40P-KS) only received some basal zinc (Zn) (1 kg Zn), with or without 40 kg P/ha, while the remaining treatments (0P, 10P, 20P and 40P) received all background nutrients in addition to 0, 10, 20, and 40kg P/ha. The commercial fertiliser products that were used to make up the treatments are listed in Table 2.

These treatments were applied using a fixed tyne implement which delivered the P and K at 20 cm depth and the N and S at 10-15 cm depth. The fertiliser bands were placed 50 cm apart in plots that were 5.4 m wide by 24 m long and in the same direction as the crop rows. Additionally this trial also had another variable applied at planting. Each deep applied treatment had ‘with’ and ‘without’ starter P (Crop King 88®) applied at planting with seed. The ‘with’ treatment was applied at a rate of 35 kg/ha. The two starter P treatments across the eight deep P treatments meant that each of the four replicates had 16 plots, for a total of 64 plots for the trial.

Wheat (cv. Rees$^{(D)}$) was planted into the P trial with the co-operators’ nine metre commercial planter on the 8 June 2016 and harvested on the 15 October. The crop was planted on 45 cm rows into good soil moisture and received 185 mm in-crop rainfall (see Trial details).

Potassium trial (K)

The potassium experiment used a similar model to that used in the P experiment, containing a farmer reference (FR) treatment and a 0K treatment. The FR treatments had no deep tillage and only the nutrients applied by the co-operator in line with normal commercial practice, benchmarking current production levels. All other treatments were ripped, and had additional N fertiliser applied (80 kg N/ha) to ensure N deficiency did not limit grain yield. The remaining treatments consisted of a range in K application rates (0, 25, 50, and 100 kg K/ha, with an additional two treatments (0K-PS, 100K-PS) receiving contrasting K rates without any background P and S applications.

Applications were done in the same way as the P trial (Table 1b). The K trial was also planted with the co-operators’ nine metre commercial planter on 45 cm row spacing and a blanket rate of starter P as a granular application (Crop King 88®) applied with the seed at planting (35 kg/ha). Plot dimensions remain the same as the P trial however there is just the eight deep applied treatments in each of the six replicates giving a total of 48 plots for the trial.

Table 1b. Summary of nutrient application rates for the potassium and sulfur trials

	N rate (kg/ha)	P rate (kg/ha)	K rate (kg/ha)	S rate (kg/ha)	Zn rate (kg/ha)
0K	80	20	0	20	2
0K	80	20	0	20	2
25K	80	20	25	20	2
50K	80	20	50	20	2
100K	80	20	100	20	2
0K-PS	80	0	0	0	2
100K-PS	80	0	100	0	2
FR	0	0	0	0	0

Table 2. 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%)
Sulfur (S)	GranAm (24%)
Zinc (Zn)	Agrichem Supa zinc (Liq) (7.5%w/v)

For both trials the collection of data was done in the same way. Plant counts, starting soil water and starting nitrogen (N) measurements were taken post emergence. Total dry matter measurements were taken at physiological maturity and yield measurements were taken with a plot harvester when commercial harvesting started in the same paddock. A harvest sample was taken from each plot and a grain sample was kept from the plot for nutrient analysis. Both the dry matter samples and the grain samples were ground down and sub-sampled for a wet chemistry analysis.

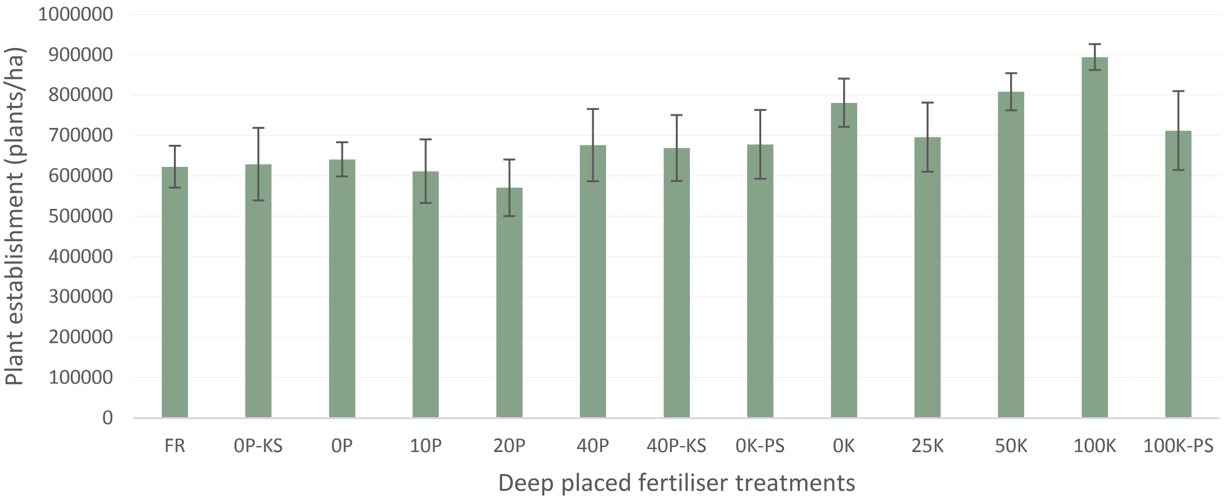


Figure 1. Summary of plant establishment across both phosphorus and potassium trials

Results

There was some variability in the established plant populations across both trials, although the P trial was more consistent with populations averaging 620,000 plants/ha. The K trial was more variable but generally established more plants at an average of 750,000 plants/ha. Results from trial worked carried out by the Variety Specific Agronomic Package project (VSAP) indicated that yields were not impacted by population in CQ if establishment was at or above 600,000 plants/m² across all varieties. This means the establishment at this site should not be limiting yield, although stand variability may have impacted on treatment precision.

Phosphorus

Table 3. Comparison of mean grain yields across deep P treatments (l.s.d=150)

	Mean grain yields (kg/ha)	LSD (P=5%)	Relative difference to '0P' treatment	
			(kg/ha)	(%)
FR	3902	a	-237	-5.7
0P-KS	4041	ab	-98	-2.4
0P	4139	b	0	0.0
10P	4082	b	-57	-1.4
20P	4174	b	34	0.8
40P	4158	b	19	0.4
40P-KS	4053	ab	-87	-2.1

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

The only significant result in this trial was that the combination of tillage and background nutrients (N, K and S) produced a slight but significant yield benefit relative to the FR control, with the former yielding nearly six percent lower than all the P treatments (Table 3). There were no significant differences between rates of deep P in the trial, and while there was a trend for a slight drop in yield without K and S (2.4% and 2.1% without and with P, respectively), these differences were not large enough to be of any statistical significance. These small changes may be an indication that wetter seasonal conditions allowed good access to nutrients normally marooned in the dry top 10 cm of the soil profile, as occurred in other trials across CQ in 2016. The nitrogen levels were good at this site, and this was reinforced by protein levels being consistently between 13.2% and 13.7%.

Early tillering filling in row spacing

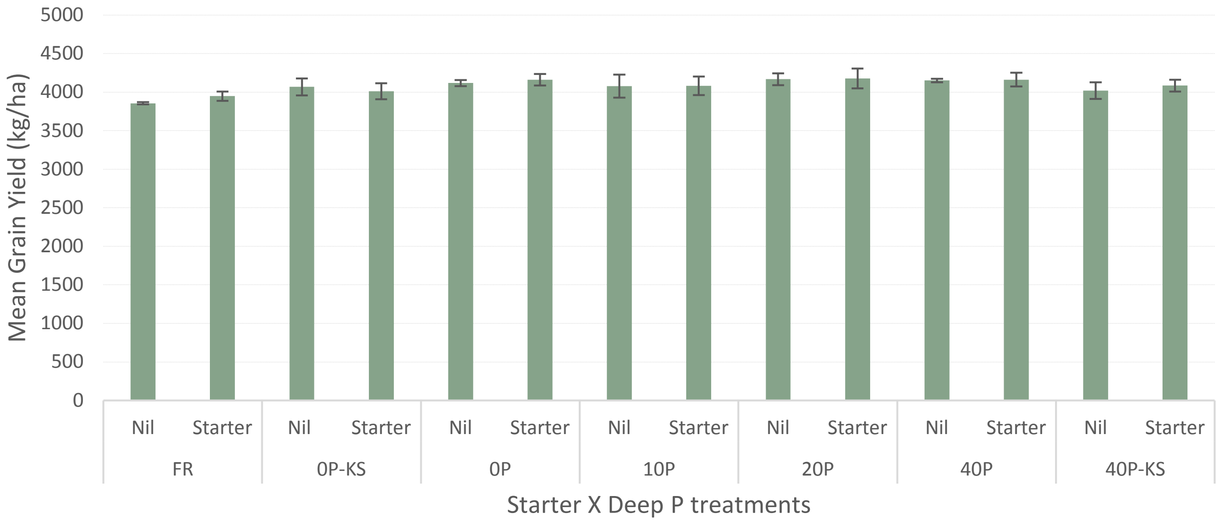


Figure 2. Impact of Starter P on grain yields across all the deep phosphorus treatments

There was no significant effect of starter P on grain yield, nor was there any significant interaction between the starter and deep placed treatments (Figure 2). Dry matter production also followed the same pattern as grain yield with the only significant difference being between the FR plots and the P treatments with background nutrition added.

Even plant maturity across both trials

Potassium

There was no significant differences between treatments in the K experiment either, although again the FR treatment yielded significantly less than all other treatments with deep ripping and variable additional nutrient inputs (Table 4). Similar to the P trial, the FR treatment was 7% worse off than the 0K-PS treatment and 10 to 11% worse than any of the deep K applications. The lack of response to K, or to background P and S, may again reflect the unusually good access to the topsoil nutrients seen in an unusually wet year. Nitrogen levels seemed to be adequate with grain proteins ranging from 12.8 to 13.4%, with no significant treatment effects on protein levels across the trial.

Table 4. Comparison of mean grain yields across deep K treatments (l.s.d. =132)

	Mean grain yields (kg/ha)	LSD (P=5%)	Relative difference to '0K' treatment	
			(kg/ha)	(%)
FR	3975	a	-367	-8.5
0K-PS	4274	b	-68	-1.6
0K	4342	bc	0	0.0
25K	4409	bc	67	1.5
50K	4282	b	-60	-1.4
100K	4444	c	102	2.4
100K-PS	4399	bc	57	1.3

Means with the same letters are not significantly different

Dry matter production also followed a similar pattern to grain yield with no significant differences across any of the deep K applications.

Implications for growers

These results were surprising given the soil analysis from this site (trial details). There is a very strong stratification of both P and K at this site with P levels dropping from 17 mg/kg (0-10 cm) to 3 mg/kg (10-30 cm) and K levels halving from 0.23 meq/100g to 0.12 meq/100g in the same depth increments. This site did have some excellent rainfall that was distributed throughout the season (trial details), so it is possible that the plants managed to access most of their P and K supply out of the surface zone (0-10 cm) especially as winter temperatures allowed the surface soil profiles to retain moisture for longer.

This data reinforces the point that seasonal conditions can have a big impact on the response to deep applied P and K especially if the surface profile (0-10 cm) is well supplied with nutrients. This needs to be confirmed by collecting further data from this site over a number of cropping years with different seasonal scenarios.

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 UQ 00063 'Regional soil testing guidelines for the northern grains region'.

Harvesting the potassium trial

Trial details

Location: Dululu

Crop: Wheat (Rees$^{Ⓓ}$)

Soil type: Brown/Grey Vertosol (brigalow scrub) undulating on minor slopes

Monthly rainfall totals (mm):

Jun-16	Jul-16	Aug-16	Sep-16	Oct-16
44	90	9	42	2

Fertiliser: 35 kg/ha CK88® applied at planting
100 kg/ha urea applied post plant as surface broadcast prior to rainfall

Selected soil fertility characteristics:

Depth (cm)	Nitrates	Colwell P	Sulfur (KCl-40)	Exc. K	BSES P	ECEC
0-10	7	17	4	0.23	21	22
10-30	22	3	7	0.12	5	28
30-60	18	1	18	0.09	4	29

Chickpea: responsive to deep applied phosphorus and potassium on scrub soils—Comet River

Doug Sands and Dr David Lester

Department of Agriculture and Fisheries

RESEARCH QUESTION: *Does the deep application of phosphorus and potassium increase chickpea yields in a soil with marginal soil test values?*

Key findings

1. 24% response to the highest rate of deep phosphorus application.
2. 9% response to starter phosphorus applied at planting.
3. No response to deep placement of potassium.

Background

Over the last three years the UQ00063 project (Regional Soil Testing Guidelines) has been establishing and monitoring a series of nutrition experimental sites across Central Queensland (CQ). These trial sites were chosen based on soil testing evidence showing varying degrees of nutrient depletion in the surface and subsurface layers. This is particularly evident in the non-mobile nutrients of phosphorus (P) and potassium (K). In some established zero tillage production systems there is a marked difference between the nutrient concentration in the top 10 cm of the soil profile and the deeper layers (10-30 cm and 30-60 cm) that cannot be explained by natural stratification. It would seem that this pattern of soil analysis is becoming more evident across CQ; particularly in the brigalow scrub and open downs soil types.

This project is determining whether the one-off application of either P, K and/or sulfur (S) that is placed in the depleted subsurface layer (20 cm) can provide a grain yield benefit and whether that benefit can be maintained over several years. These results can also be used to define the economic benefit of a once off application over successive cropping cycles.

What was done

This trial site was established in October 2015 and then planted to chickpeas in June 2016, consequently this trial report is the first set of cropping data from this site. Based on the information contained in the original soil characterisation tests (see Trial details) it was decided to locate two individual rate response trials at this site: one each for P and K.

Phosphorus trial (P)

There were eight treatments in total (Table 1a), which included four P rates; 0, 10, 20, and 40 kg P/ha (0P, 10P, 20P and 40P).

Table 1a. Summary of nutrient application rates for the phosphorus trial treatments

		Rate (kg/ha)					
Main label	Starter label	N	Starter P	P	K	S	Zn
0P	Nil starter	80	0	0	50	20	2
0P	Starter	80	6	0	50	20	2
10P	Nil starter	80	0	10	50	20	2
10P	Starter	80	6	10	50	20	2
20P	Nil starter	80	0	20	50	20	2
20P	Starter	80	6	20	50	20	2
40P	Nil starter	80	0	40	50	20	2
40P	Starter	80	6	40	50	20	2
40P-KS	Nil starter	80	0	40	0	0	2
40P-KS	Starter	80	6	40	0	0	2
0P -KS	Nil starter	80	0	0	0	0	2
0P -KS	Starter	80	6	0	0	0	2
FR	Nil starter	0	0	0	0	0	0
FR	Starter	0	6	0	0	0	0

All treatments had background fertiliser applied at the same time to negate any other limiting nutrients. This basal fertiliser was 80 kg nitrogen (N)/ha, 50 kg K/ha, 20 kg S/ha and 1 kg zinc (Zn)/ha. Two contrasting treatments included 0P and 40P without any background K and S fertiliser (0P-KS, 40P-KS) to assess the impact of P only. The last two treatments were, a farmer reference (FR) plot and an extra 0P plot; to give two controls for each replicate. The FR treatments had nothing applied except what the farmer applies in line with normal commercial practice, benchmarking current production levels. Commercial fertiliser products were used to make up the treatments (Table 2).

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 fertiliser bands were placed 50 cm apart in plots that were 6 m wide by 32 m long and in the same direction as the crop rows. Additionally this trial also had another variable applied at planting. Each deep applied treatment had 'with' and 'without' starter P (Granulock Supreme Z®) applied at planting with seed. The 'with' treatment was applied at a rate of 30 kg/ha. The two starter P treatments across the eight deep P treatments meant that each of the six replicates had 16 plots, for a total of 96 plots for the trial.

Chickpea (variety—Kyabra$^{\phi}$) was planted into the P trial with a 2 m plot planter on 28 June 2016 and harvested on 10 November. The crop was planted on 50 cm rows into good soil moisture and received 235 mm in-crop rainfall (see Trial details).

Potassium trial (K)

The potassium experiment is exploring application of K with/without P and S being present. There were eight treatments including 4 K rates: 0, 25, 50, and 100 kg K/ha with a background fertiliser of 80 kg N/ha, 20 kg P/ha, 20 kg S/ha and 1 kg Zn/ha. Contrasting this were two treatments 0K and 100K without PS fertiliser (0K-PS, 100K-PS). Remaining treatments were a farmer reference (FR) and an extra 0K to give two controls in each replicate. The FR plots were not treated with anything except what the farmer applies in line with normal commercial practice.

Applications were done in the same way as the P trial (Table 1b). The K trial was also planted with a 2 m plot planter on 50 cm row spacing and a blanket rate of starter P as a granular application (Granulock Supreme Z®) applied with the seed at planting. Plot dimensions remained the same as the P trial however there were just the eight deep applied treatments in each of the six replicates giving a total of 48 plots for the trial.

Table 1b. Summary of nutrient application rates for the K and S trial treatments

Main label	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Zn (kg/ha)
0K	80	20	0	20	2
0K	80	20	0	20	2
25K	80	20	25	20	2
50K	80	20	50	20	2
100K	80	20	100	20	2
0K-PS	80	0	0	0	2
100K-PS	80	0	100	0	2
FR	0	0	0	0	0

Table 2. 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%)
Sulfur (S)	GranAm (24%)
Zinc (Zn)	Agrichem Supa zinc (Liq) (7.5%w/v)

For both trials the collection of data was done in the same way. Plant counts, starting soil water and starting N measurements were taken post emergence. Total dry matter measurements were taken at physiological maturity and yield measurements were taken with a plot harvester when commercial harvesting started in the same paddock. Two harvest samples were taken from each plot and a grain sample was kept from the plot for nutrient analysis. Both the dry matter samples and the grain samples were ground down and subsampled for a wet chemistry analysis.

Results

Established plant populations were below targets with most plots averaging 12 plants/m^2. This may have affected top end yield but the population density was uniform across the trial site so treatment comparisons were not unduly influenced by this variable.

Phosphorus trial

The starter P applications showed consistent differences across all treatments except the 0P-KS plots (Figure 1). The average treatment effect from starter P was 195 kg/ha (9.6%) which was significant at the 5% level. This is unexpected given that the surface Colwell P

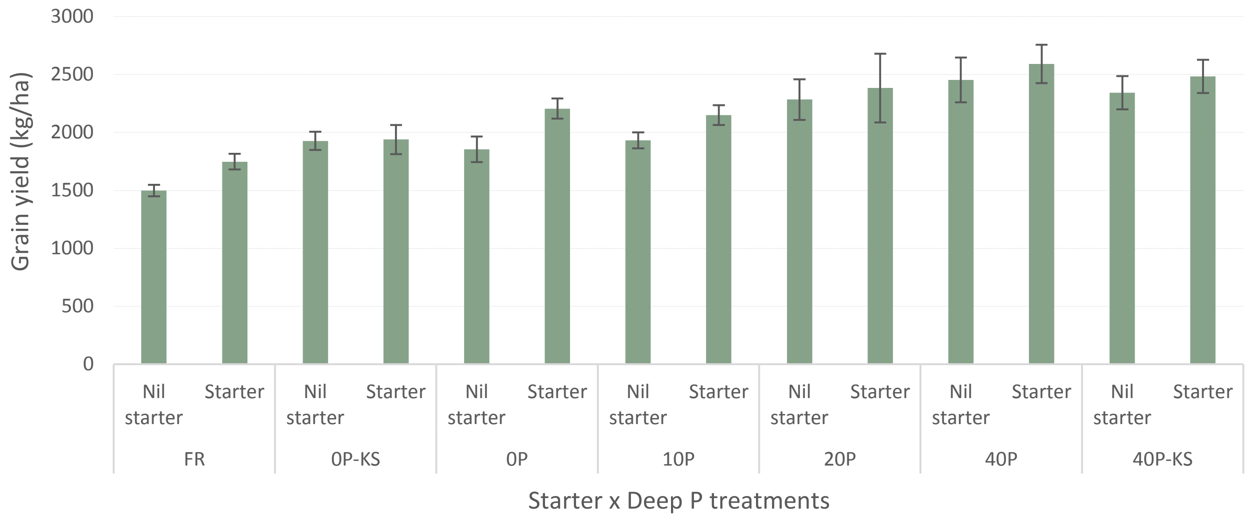


Figure 1. Comparison of starter treatments across all deep P treatments
Means for Starter = 2214 kg/ha, Nil starter = 2019 kg/ha (l.s.d = 133)

levels were good (between 18-22 mg/kg) and there was significant in-crop rainfall (234 mm).

There is also a significant response to deep applied P with the top rate of P producing a 24% yield gain (Table 3). There was a significant rate response between the 10P rate and the 20P rate of 300 kg/ha of grain (14%). This might indicate that the concentration of the fertiliser in the band is having an impact in relation to root access to the nutrition. The higher the concentration in the band the bigger the concentration gradient between the root surface and the fertiliser band, making it easier for nutrient absorption into the plant.

Differences in early growth prior to flower, foreground FR plot, background is 40P plot

The FR plots were significantly lower than all other treatments with a 15% reduction in yield compared to the 0P-KS plots (Table 3). This could indicate that the site has a compaction issue as the only difference between these two treatments is deep ripping and additional nitrogen. The additional nitrogen may have been of some benefit but generally chickpeas are not responsive to nitrogen given that it fixes its own.

Table 3. Comparison of mean grain yields across deep placement treatments in phosphorus trial

Label	Mean grain yield (kg/ha)	LSD test (P=5%)	Relative yield difference to '0P' plots (kg/ha)	Relative yield difference to '0P' plots (%)
FR	1624	a	-408	-20.1
0P-KS	1934	b	-97	-4.8
0P	2031	b	0	0.0
10P	2041	b	10	0.5
20P	2335	c	303	14.9
40P	2523	c	492	24.2
40P-KS	2413	c	382	18.8

Means without a common letter are significantly different (l.s.d = 231)

Potassium trial

Although there was a significant responses within the K trial, there was actually no response to additional deep applied K. The 0K, 25K and 100K rates were all similar in response and the 50K rate had a negative response (Figure 2), which cannot be explained and may be part of natural variability. The main significant response in this trial has been from the treatments that did not have any P applied as background

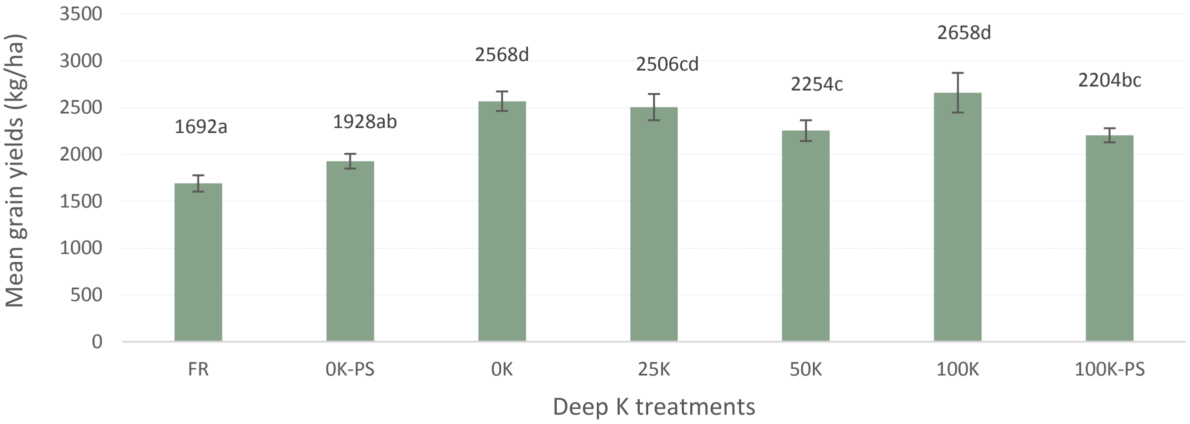


Figure 2. Comparison of mean grain yields across all deep K treatments (means with the same letters are not significantly different, l.s.d = 279)

fertiliser (FR, 0K-PS, 100K-PS). There was a 640 kg/ha difference (33%) between the zero plots with and without deep P and a 454 kg/ha difference (20%) between the 100K plots with and without deep P. This data reinforces the fact that P is the most critical nutrient limiting yield at this site.

This site should be K responsive once the P response is satisfied given the soil test values for K in the 10-60 cm layers (see trial details). However the soil test shows good levels of K in the surface profile (0.46 meq/100g) and there were several in-crop rainfall events in the first three months of the crop (see trial details). This may mean that the plant managed to access enough K out of the surface soil after each rain event to meets its needs.

Good pod set in plots with background P fertiliser added

Implications for growers

This trial has demonstrated that when soil test values for Colwell P are 5 mg/kg or less in the subsurface profile then there is a strong response to deep placed P regardless of seasonal conditions. This site had adequate P levels in the surface 10 cm profile and plenty of in-crop rainfall but it still responded to the additional P fertiliser even though it should have had access to surface P on regular occasions.

The cation exchange capacity (CEC) for this site, of 20 meq/100g, is on the lower end of the scale for cropping soils in CQ. This does indicate a lighter clay soil type, particularly in the top 30 cm of the profile. Less clay in the surface means the surface soil does dry out faster and consequently more reliance on root proliferation in the subsurface where the moisture is more reliable. Lower clay content can also mean less buffering capacity for P; this in turn means the concentrated bands of P fertiliser will create a greater concentration gradient to the plant roots and assist in uptake efficiency.

CEC can also play a role in the efficiency of K fertiliser use. A low CEC will mean a lower K buffer capacity, and hence a higher soil solution K concentration. This allows the development of steeper gradients in solution K concentration when plant roots are active, and should result in a more efficient pathway for K diffusion to the root system; particular when soils stay wet. This may be one reason why the response to K in this site was minimal.

Plant responses to critical soil test values for P and K, especially in subsoils, are influenced by a number of variables that have an impact on the supply of P and K to the plant. This can include both seasonal conditions as well as physical soil characteristics. It is important to understand both when evaluating the responses to deep applied P and K.

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 UQ 00063 'Regional soil testing guidelines for the northern grains region'.

Trial details

Location:	Comet River, east of Gindie
Crop:	Chickpeas (Kyabra$^{⚘}$)
Soil type:	Brown Vertosol (mixed scrub) undulating on minor slopes
In-crop rainfall:	Jul 16: 113 mm Aug-16: 42.5 mm Sep-16: 57 mm Oct-16: 16 mm Nov-16: 6 mm
Fertiliser:	30 kg/ha of Supreme Z® applied at planting

Selected soil fertility characteristics:

Depth (cm)	Nitrates	Colwell P	Sulfur (KCl-40)	Exc. K	BSES P	ECEC
0-10	8	22	4.5	0.46	24	20
10-30	10	5	5.3	0.12	5	21
30-60	7	< 2	4.3	0.1	3	27

Chickpea: production five years after deep PKS application—Capella

Doug Sands and Dr David Lester

Department of Agriculture and Fisheries

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

Key findings

1. Average grain yield response of up to 12% (278 kg) to deep placement of phosphorus, potassium and sulfur; five years after the original application.

Background

There is some soil testing evidence to suggest that nutrient stratification of non-mobile nutrients such as phosphorous (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 soil profile along with the application of starter fertilisers.

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 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.

What was done

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

- 2012 chickpeas
- 2013 wheat
- 2014 chickpeas
- 2015 sorghum
- 2016 chickpeas

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

There were 10 treatments replicated six times, with treatments described in Table 1.

Table 1. Treatment summary

Treatment	Nutrient (kg/ha)									
	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	-	-	-	0.0	0.0	0.0	0.0	0	0.0
10. P:K:S-TE	100	40	200	40	0.0	0.0	0.0	0.0	0	0.0

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 effects across the site. The trial had 12 plots per replicate and 72 plots for the whole trial. These 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 tyne 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 are 18 m wide from centre to centre. All crops were planted and sprayed by the grower co-operator as part of the normal management regime.

The 2016 chickpea crop had 25 kg/ha of a starter blend similar to CK55. Pistol was planted at 50 kg/ha on 50 cm rows on 11 May 2016 and harvested on the 14 October 2016. The crop received a total of 289 mm of rainfall with 60% of this falling in the first week of 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 measure 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

The chickpea crop of 2016 has shown a small response to treatments with P applied in combination with the other macronutrients (Figure 1). Unusually the treatments where P was applied on its own did not respond any better than the control treatments but those P treatments in combination with sulfur (S) and K all showed a small response. This was very similar to the response that occurred in the 2014 chickpea crop where both the combinations of P:K and P:S gave a response but not P on its own (Table 2).

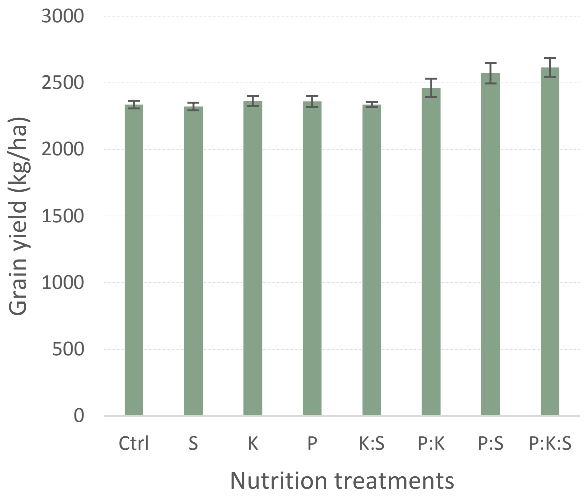


Figure 1. Average grain yield response across deep placed PKS treatments in 2016 chickpeas

Over the five crops that have been harvested at this site there has been a consistent response to P (Table 2), except in the 2015 sorghum crop where low grain proteins (averaged 7.5%) suggested that nitrogen (N) supply was restricted and yield responses to P/K/S could not be expressed. This is reinforced by the fact that the chickpeas in the following year (where N supply is not a factor) has produced a similar pattern of response to previous chickpea crops.

The 2016 chickpea crop highlights a slight change in the pattern of response in relation to other years (Figure 2). The P:S and the P:K:S combinations have achieved a 10% or better response over the average of the control plots. However the P:K combination has struggled to achieve a 5% response (Figure 2). In nearly all other years the P:K results have been similar to P:K:S. There are a number of possible explanations for this.

Table 2. Comparison of average grain yields (t/ha) across all nutrient treatments in five successive crops (2012 to 2016)

Site and crop/year	Control	S	K	P	K:S	P:K	P:S	P:K:S	LSD (P<0.05)
					Yield (kg/ha)				
Chickpea 2012	2318	2357	2386	2782	2348	2899	2806	2832	170
Wheat 2013	2100	2178	2185	2247	2199	2359	2248	2348	90
Chickpea 2014	1595	1615	1683	1693	1696	1782	1743	1875	100
Sorghum 2015	3053	3065	3097	3095	3053	3057	3111	3141	200
Chickpea 2016	2337	2324	2364	2361	2337	2463	2572	2615	174

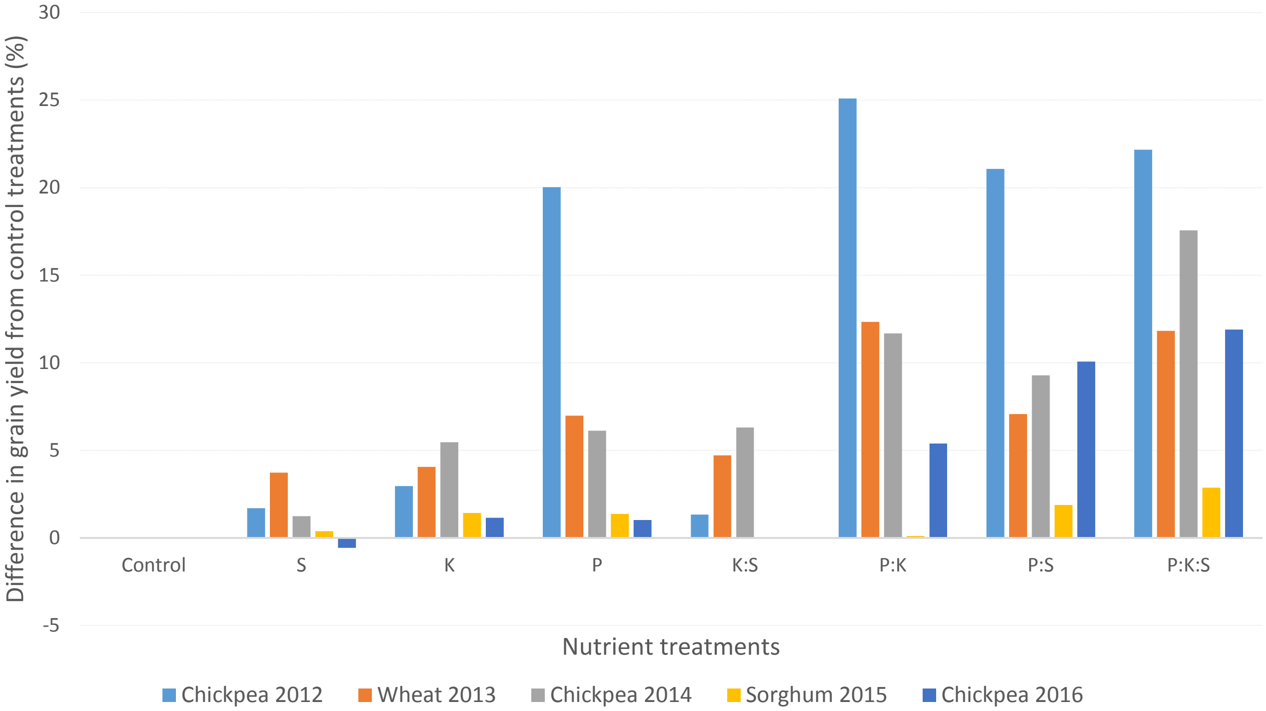


Figure 2. Relative difference of grain yields for deep placed nutrient treatments as a percentage of the control across all crops

The first hypothesis is that S could be starting to be a more limiting nutrient over time at this site—although the lack of an S response when applied alone suggests that it is still not the most limiting nutrient. The 2016 data actually suggests that P, K and S availability in the subsoil are now all low enough to limit crop performance, so no single nutrient on its own can change crop response unless the other two are also present. This might explain why in the last two chickpea crops the multiple combination of P:K:S have been the top yielding treatment. This theory is consistent with the soil test analysis (see trial details) that would suggest that all three nutrients are low in the subsurface profile.

Another variable that could be affecting responses is the amount of in-crop rainfall that occurred in each cropping season (Table 3). The 2016 season has by far exceeded all other seasons for rainfall and a large percentage of it was around the start of flowering. This has meant that the crop has had greater access to surface nutrients (0-10 cm) during its key growth stages and less reliance on the subsurface nutrients (10-30 cm). This may also explain why the P: K treatment was less effective in this season (Figure 2); there is more K available in the surface soil then S (see trial details), and in wet seasons like 2016 this would have been more accessible. This would mean the plant did not need to access the deep banded K, but needed to find additional S against low and declining reserves—especially with the crop having a higher yield potential and hence nutrient demand set up by the amount of in-crop rainfall received. The co-operator has continued to apply starter fertilisers such as CK55 each year into the surface profile, but at low rates; which supplies good levels of P (14.2%) and K (12.5%) but only small amounts of S (1.2%).

Table 3. Summary of in-crop rainfall for the five successive crops grown at Capella

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
2016 Chickpeas	289 mm	60% of rainfall in the first week of flowering

Overall the 2016 chickpea result has proven a response to deep applied P, K and S is possible five years after the initial application. Although there a number of variables at play impacting on the size of the response in any one season, there has been a consistent 12-18% response to the combination of P:K:S across all crops.

Implications for growers

The longevity and efficacy of deep placement of phosphorous based fertilisers in cracking vertosol soils is dependent on a number of variables. These variables include crop species (root development), variations of in-crop rainfall, yield potential, concentration of the fertiliser band and the broader soil fertility levels—particularly nitrogen. This site has shown consistent responses to deep placed P in combination with K and S of between 12-18% except where the nitrogen supply has been limited (Sorghum 2015). P has been the most critical limitation as the K: S combination has never given any significant response over five years, which suggests that K and S limitations have been secondary to that of P at this site—at least until 2016.

In a site where there are multiple nutrient deficits in the subsurface, along with a requirement to apply N to meet crop demand, balancing the nutrient supply through annual applications is almost impossible except for N. This trial site has given some evidence that robust applications of immobile nutrients like P and K, in addition to slightly more mobile nutrients like S, can continue to provide yield responses for up to five years. However, ensuring adequate N is available on a year-by year basis is essential to achieve these responses. There has been a stronger and more consistent response to combinations of applied nutrients (P: K: S) than to applications of single nutrients (P, K or S), highlighting that the dominant constraint at such sites can change with seasonal conditions that affect root distribution and crop demand. These types of multi-nutrient responses are governed by the characteristics of each soil type, but it reinforces how important it is to get the balance of macro nutrients (N, P, K, and S) right to optimise use of seasonally available water.

This trial site is the first set of CQ data to show this kind of longevity in plant response. The three year extension to UQ00063 should result in a number of other CQ sites being monitored over a similar period. This longevity of trial data is essential to assess the economics of longer term nutrient management options like deep banding.

Acknowledgements

It is greatly appreciated to have the continued support of trial co-operators, by hosting this trial site. This work is funded by Canpotex P/L, the International Plant Nutrition Institute (IPNI), the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ 00063 'Regional soil testing guidelines for the northern grains region'.

2016 chickpea crop

Trial details

Location: North, west of Capella

Crop: Chickpea (Pistol$^{\phi}$) 2016

Soil type: Downs, cracking Black Vertosol

Monthly rainfall (mm):

May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Total
0	70	175	24	21	0	289

Fertiliser: 25 kg/ha CK55 or equivalent at planting

Selected soil fertility characteristics:

Depth (cm)	Col P (mg/kg)	BSES P (mg/kg)	PBI	Exc. K (meq/100g)	ECEC (meq/100g)	S - 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

Chickpea: production five years after deep PKS application—Gindie

Doug Sands and Dr David Lester

Department of Agriculture and Fisheries

RESEARCH QUESTION: *Does the application of immobile nutrients such as phosphorous and potassium continue to improve yields five years after the initial deep placement application?*

Key findings

1. No yield or dry matter response in the 2016 chickpea crop.
2. Nutrient uptake from deep placed bands impacted by the amount and spread of in-crop rainfall.
3. Deep placed nutrient bands still available five years after application.

Background

There is some soil testing evidence to suggest that nutrient stratification of non-mobile nutrients such as phosphorous (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 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 then it can 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 (if other nutrients are non-limiting), and if this can last for multiple crop cycles.

What was done

The treatments at this site were established in October of 2011. The 2016 chickpea crop was the fourth crop harvested from this trial. Since application of the treatments; crops planted include sorghum (2012), chickpeas (2013), sorghum (2015) and chickpeas (2016). Each crop has had starter fertiliser applied in the top 10 cm at planting and also some additional nitrogen for the sorghum crops (110–120 kg/ha of urea). There were eight treatments replicated six times (Table 1).

Table 1. Treatment description

Treatment	Nutrient (kg/ha)									
	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)

Table 2. Grain yield results across all treatments for all 4 crops harvested from the site since 2011

Crop/year	Control	S	P	K	K:S	P:S	P:K	P:K:S	LSD (P<0.05)
					Yield (kg/ha)				
Sorghum 2011-12	2803	3105	3233	2721	2840	3435	3198	3491	363
Chickpeas 2013	1148	1207	1318	1468	1513	1182	1743	1607	260
Sorghum 2014-15	2954	2890	2952	3446	3198	3273	3397	3108	200
Chickpeas 2016	2345	2437	2445	2485	2248	2412	2493	2395	221

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. These 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 tyne implement. The plots were 32 m long by 8 m wide; 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 2016 chickpea crop was planted with 30 kg/ha of a starter blend based on CK55S. Kyabra$^{\Phi}$ was planted at 55 kg/ha on 50 cm rows on 11 May 2016 and harvested on 19 October 2016. The crop received a total of 291 mm of in-crop rainfall.

Total biomass samples were cut at maximum dry matter accumulation or when the grain was at the soft dough stage, then dried and weighed. Selected samples were ground down for nutrient analysis. Grain yields were measure by harvesting one strip 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

The 2016 chickpea crop has shown no significant differences between treatments despite the previous three crop results showing strong responses to either P and/or K (Table 2). 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 which was unexpected given that the first sorghum crop did not produce a response to K. Seasonal conditions may have contributed to this difference, but results suggest that both P and K were low at this site. This is supported by the data that showed in both crops where K gave a significant benefit as a single nutrient application, the addition of P seemed to have an additive effect to produce an even larger response (e.g. an additional 275 kg in 2013 chickpeas).

It is worth noting the big differences in relative response over the four crops. The early sorghum and chickpea crops had large percentage responses over the controls (Figure 1) but the

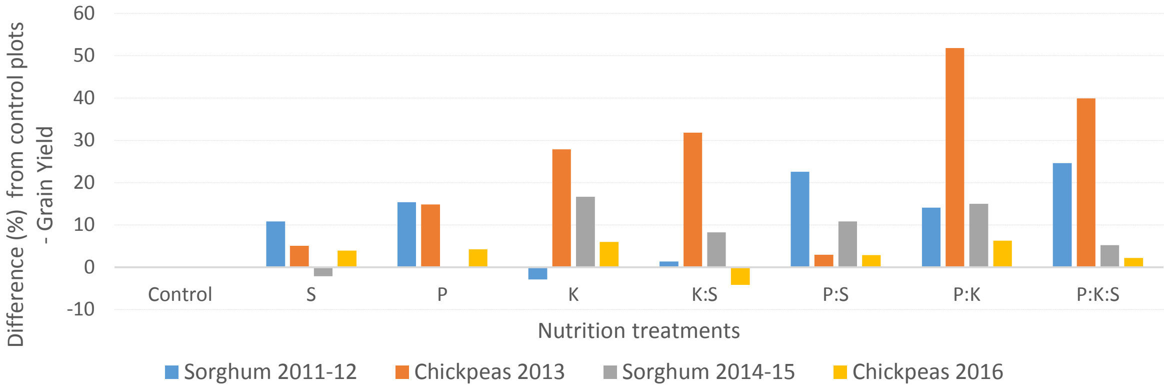


Figure 1. Relative difference of grain yields for deep placed nutrient treatments as a percentage of the control across all crops

last sorghum crop in 2015 had much smaller differences and the last chickpea crop in 2016 had no significant differences at all. While it may be tempting to suggest that the declining responses over time are indicative of a rundown in availability of the applied fertiliser nutrient, this is not consistent with observations at other sites. The impact of seasonal rainfall patterns (amounts and distribution) that effect root distribution, as well as differences in crop species sensitivity to marginal soil nutrient reserves, also need to be considered.

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

Crop year	In-crop rainfall	Comments
2012 Sorghum	540 mm	35% post flower
2013 Chickpeas	9 mm	Small falls, no impact
2015 Sorghum	244mm	96% prior to flowering
2016 Chickpeas	291 mm	74% before podding started

There is a stark contrast between the in-crop rainfall received by the 2013 chickpea crop and the 2016 chickpea crop (Table 3), and this factor may well be the major difference between the relative response profiles. The 2016 chickpea crop had ample opportunity to source nutrients from the surface soil, which has medium levels of P and K (see Trial details)—not only because of the many in-crop rainfall events but also because of the lower evaporation levels during winter which would allow the surface soil to stay wet for longer. In other words, the crop root system did not need to draw on the deep placed bands to get enough P or K to meet demand.

Dry matter analysis for K concentration in the plant material (Figure 3) suggests that the plant did have access to the deep placed bands of fertiliser, as K concentrations were significantly higher in the plants in treatments that had extra K applied in relation to the controls. However this was not the same for P concentration as there were no significant differences between the P treatments and the control plots (Figure 2).

The deep applied P and K bands were placed together in the soil profile so if the roots had access to the applied K it should also have access to the applied P. The plant tissue analysis (Figures 2 and 3) would suggest that this has not happened, although there are differences in how plants respond to a supply of P and K that exceeds crop requirements.

It is generally accepted that some species of crops are able to take up more K than is necessary for healthy growth, sometimes known as 'luxury consumption'; although this tends to be more evident in lighter textured soils where the supply processes allow efficient capture of soil K. In contrast, P uptake normally runs in parallel with dry matter production and luxury accumulation is less pronounced—although it can still occur.

The relative differences in crop demand for P and K are also significant; each tonne of dry matter accumulated 5-10 times as much K as P (e.g. Figures 2 and 3). The starter fertiliser inputs were therefore significant in terms of P (4 kg P/ha—enough to produce an additional 2-3 t/ha dry matter is all taken up), but very minor in terms of K (3.5 kg K/ha—enough to produce an additional 300 kg/ha dry matter). It is therefore possible that the combination of efficient use of starter fertiliser and the relatively P-enriched topsoil was adequate to meet P demand, but not enough to prevent the crop drawing significantly on the reserves in the K bands.

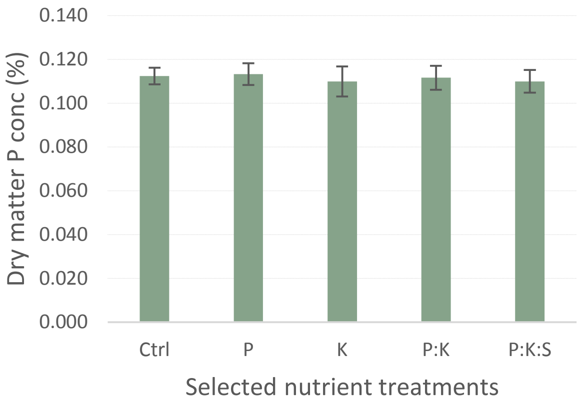


Figure 2. Concentration of P in dry matter for 2016 chickpeas (l.s.d = 0.0155)

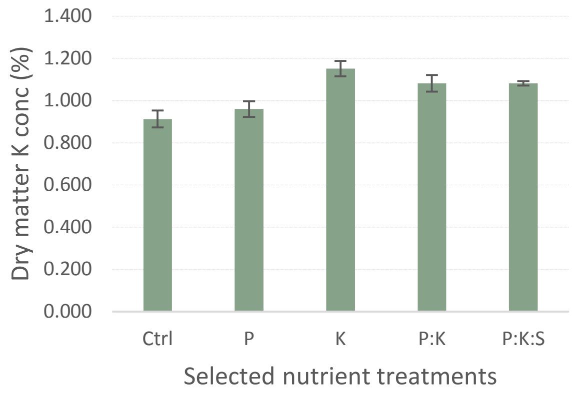


Figure 3. Concentration of K in dry matter for 2016 chickpeas (l.s.d = 0.109)

Based on this evidence it could be argued that although the plants root system had access to the banded nutrition it did not need to utilise it to grow additional biomass or grain yield; because it had easy access to nutrients in the shallower soil profile by way of regular in-crop rainfall. In seasons like this, utilisation of starter fertiliser is also likely to be quite efficient, with inputs of P from this source likely to be much more significant than that of K. That said, it is clear that crops were still accessing residual K from the deep bands applied in 2011. The availability of deep banded P could not be determined from this season.


Harvest 2016 chickpeas; visually crop is very even across treatments at maturity


2013 chickpeas; big visual differences between treatments

Implications for growers

This long term trial has shown 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 K as the most limiting nutrient, with only 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 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, but like the contrast in seasonal responses by the two chickpea crops, the relative access to topsoil layers at different stages of the crop season may have been significant.

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 non-mobile nutrients. The chickpea crop in 2013 at this site had no in-crop rainfall and grew entirely on stored soil moisture and had a spectacular 51% response to the P: K treatments, whereas the next chickpea crop in 2016 had over 290 mm of in-crop rainfall and gave no response to deep P and K bands. On evaluation of the 2016 results, it would seem that the deep banded P and K are still present and available some five years after the original application. The lack of yield response was consistent with the unusually large amount and even spread of the in-crop rainfall that would have increased plant access to the nutrition in the soils surface profile.

Acknowledgements

It is greatly appreciated to have the continued support of trial co-operators, by hosting this trial site. This work is funded by Canpotex P/L, International Plant Nutrition Institute (IPNI), the Grains Research and Development Corporation and the Department of Agriculture and Fisheries under UQ 00063 ‘Regional soil testing guidelines for the northern grains region’.

Trial details

Location: East of Gindie

Crop: Chickpea (Kyabra$^{\phi}$) 2016

Soil type: Brigalow scrubs, cracking Black/Grey Vertosol

Monthly rainfall 2016 (mm):

May	Jun	Jul	Aug	Sep	Oct	Total
0	88	126	18	57	2	291

Fertiliser: 30 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	0.20	39.42
10-30	4	4	140	0.06	42.47
30-60	4	4	150	0.05	44.83

Sorghum: residual value of deep placed phosphorus, potassium and sulfur in scrub soils—Dysart

Doug Sands and Dr David Lester

Department of Agriculture and Fisheries

Research Question: *Does the deep placement of phosphorus, potassium and sulfur have an impact on sorghum yields three years after the original application?*

Key findings

1. Response to deep placed phosphorus in third sorghum crop of 15%.
2. No significant response to deep placed potassium or sulfur in third sorghum crop.

Background

Over the last three years the UQ00063 project (Regional Soil Testing Guidelines) has been establishing a series of nutrition based trial sites across Central Queensland (CQ). These trial sites were chosen based on soil testing evidence showing varying degrees of nutrient depletion in the surface and subsurface layers. This is particularly evident in the non-mobile nutrients of phosphorus (P) and potassium (K). In some established zero tillage production systems there is a marked difference between the nutrient concentration in the top 10 cm of the soil profile and the deeper layers (10-30 cm and 30-60 cm) that cannot be explained by natural stratification. It would seem that this pattern of soil analysis is becoming more evident across CQ and particularly in the brigalow scrub and open downs soil types.

This project is gathering data from these trial sites to ascertain whether the one-off application of either P, K or sulfur (S) that is placed in these deeper more depleted layers can provide a grain yield benefit and whether that benefit can be maintained over several years. These results can also be used to define the economic benefit of adding these non-mobile nutrients over successive cropping cycles.

What was done?

The treatments at this site were established in August 2013. Since then, there has been three successive sorghum crops grown on the site; the most recent was harvested on 7 July 2016. Each of these crops have been monitored for response to the original deep placed fertiliser treatments both in grain yield and dry matter production. Additionally, both the dry matter samples and grain samples have had tissue analysis to quantify the nutrient uptake values of the crop.

Phosphorous trial (P)

The eight treatments included four P rates (0, 10, 20, and 40 kg P/ha) with background fertiliser (80 kg nitrogen (N), 50 kg of K, 20 kg S and 0.5 kg zinc (Zn) per hectare) applied at the same time to negate any other potentially limiting nutrients. Other treatments included 0P and 40P without background fertiliser except N and Zn (0P-KS, 40P-KS), a farmer reference (FR) plot, and an extra 0P plot to give two controls for each replicate. The FR mirrored what the farmer applied in line with normal commercial practice, with nothing else added (Table 1).

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 x 32 m. The bands were place in the same direction as the old stubble rows. There were six replicates making a total of 48 plots for the trial.

The 2016 crop received 100 kg/ha of urea, applied between the one metre rows, two weeks after planting. There was no starter fertiliser applied at planting. The sorghum variety, MR Taurus, was planted at 55,000 seeds/ha on 17 February 2016. The crop received 202 mm of in-crop rainfall, 50% of which occurred after the grain had reached physiological maturity.

Potassium trial (K)

The eight treatments included four K rates (0, 25, 50, 100 kg K/ha) with background fertiliser applied (80 kg N, 20 kg P, 20 kg S and 0.5 kg Zn per hectare) at the same time to negate any other potentially limiting nutrients. Other treatments included 0K and 100K without any background fertiliser except N and Zn (0K-PS, 100K-PS), a farmer reference (FR), 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 (Table 1).

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

Sulfur trial (S)

The eight treatments included four S rates (0, 10, 20, 30 kg S/ha) with background fertiliser (80 kg N, 20 kg P, 50 kg K and 0.5 kg Zn per hectare) applied at the same time to negate any other potentially limiting nutrients.

Table 1. Summary of nutrient application rates (kg/ha) for all trials

Trial	Treatment label	N	P	K	S	Zn
Phosphorus	0P	80	0	50	20	0.5
	0P	80	0	50	20	0.5
	10P	80	10	50	20	0.5
	20P	80	20	50	20	0.5
	40P	80	40	50	20	0.5
	0P-KS	80	0	0	0	0.5
	40P-KS	80	40	0	0	0.5
	FR	0	0	0	0	0
Potassium	0K	80	20	0	20	0.5
	0K	80	20	0	20	0.5
	25K	80	20	25	20	0.5
	50K	80	20	50	20	0.5
	100K	80	20	100	20	0.5
	0K-PS	80	0	0	0	0.5
	100K-PS	80	0	100	0	0.5
	FR	0	0	0	0	0
Sulfur	0S	80	20	50	0	0.5
	0S	80	20	50	0	0.5
	10S	80	20	50	10	0.5
	20S	80	20	50	20	0.5
	30S	80	20	50	30	0.5
	0S-PK	80	0	0	0	0.5
	30S-PK	80	0	0	30	0.5
	FR	0	0	0	0	0

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 1).

Results

The results are presented on each trial separately. The 2016 crop represents the third sorghum crop harvested off this site since the initial treatments were applied. Included in this current year results is the cumulative mean yield data from all three crops.

Phosphorus trial

A significant difference in grain yield for the two highest P rates (20P, 40P) (Table 2).

Table 2. Mean grain yield comparison across treatments in P trial for sorghum 2016

Treatments	Mean grain yields (kg/ha)	Least significance difference (P=5%)	Relative difference to '0P' plots (kg/ha)	Relative difference to '0P' plots (%)
FR	1787	a	-322	-15.3%
0P-KS	2010	abc	-99	-4.7%
0P	2109	bc	0	0.0%
10P	2262	cd	153	7.3%
20P	2433	d	324	15.3%
40P	2394	d	285	13.5%
40P-KS	2029	ab	-80	-3.8%

Means with a common letter are not significantly different (l.s.d=219)

The 2016 data does not show as large a response as the previous two years as there was a lot more variability in the individual plot data. This could be attributed to two things. Firstly the crop had no in-crop rainfall for the last two and half months leading up to and including grain fill which has increased the incidence of lodging throughout the trial. Secondly the near infrared (NIR) grain protein (Figure 1) would suggest that nitrogen was a limiting factor for this crop as all the treatments were averaging 8% protein or less. Urea was applied to this trial two weeks after planting, however it was applied in the top 10 cm onto wet soil and then had follow up rainfall two weeks later. This scenario would suggest the nitrogen got trapped in the top 10 cm of the profile where the plant could not access it during flowering and grain fill. Starting N measurements taken before the urea application, shows 21 kg N/ha in the top 120 cm (see Trial details).

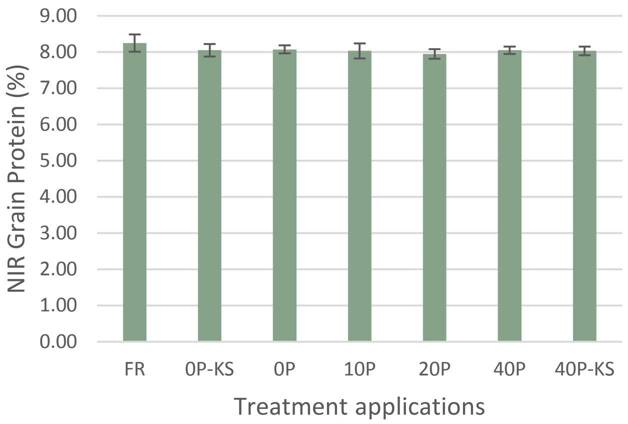


Figure 1. Average grain proteins for sorghum measured by near infrared in P trial

Difficult to see visual responses in flowering. FR plot on the left, versus 40P-KS on the right

The uniformity of the grain protein levels across all treatments would suggest that nitrogen could be limiting the response to P. In previous years it has been noted that N uptake in the high P treatments has been significantly higher than the 0P and FR plots at this site; consequently leading to higher proteins under normal circumstances. The fact that this has not occurred this year adds weight to the argument that limited access to N has reduced the response to P.

A consistent response to the two highest rates of P of 15% (1216 kg/ha) was seen in relation to the 0P treatment (Figure 2). This is in contrast to the 22% response that was achieved in the first crop in 2014. In comparison to the FR plots there was an average response of 26% (2144 kg/ha) over three years, however this response was due to a number of variables including additional nitrogen, zinc and potassium on top of the base P response.

Potassium trial

There were no significant differences for potassium application on its own even though the trend shows up to a 7% increase in yields for the 25K and 50K treatments (Table 3).

Table 3. Comparison of mean grain yields across treatments in K trial for sorghum 2016

Treatments	Mean Grain Yields (kg/ha)	Least significant difference (P=5%)	Relative difference to '0K' (kg/ha)	Relative difference to '0K' (%)
FR	2452	ab	-65	-2.6
0K-PS	2423	a	-94	-3.7
0K	2517	ab	0	0.0
25K	2696	ab	179	7.1
50K	2710	b	194	7.7
100K	2626	ab	109	4.3
100K-PS	2519	ab	2	0.1

Means with the same letter are not significantly different (l.s.d=238)

The yields in this trial have been affected by a dry finish and some lodging across the trial which has increased the level of natural variability from plot to plot. The performance of the FR plots (no extra N applied) in relation to 0K-PS would indicate that the additional N that

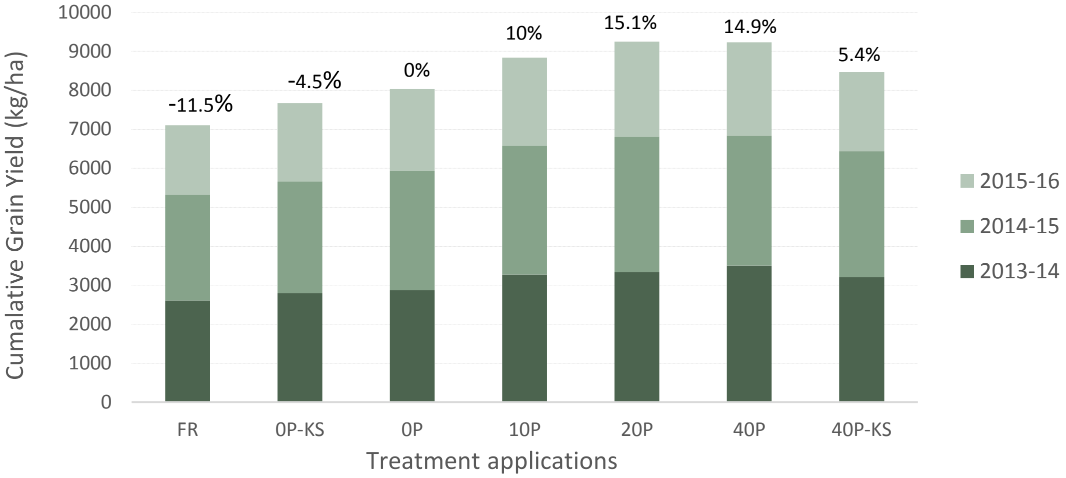


Figure 2. Accumulated grain yields across all P treatments over three successive sorghum crops

was applied during the initial application, as background nutrition, has run out. Additionally the fact that there is little difference between the grain proteins from these two treatments (0K-PS, 8.53 and FR, 8.28) is further evidence of low N supply and this is impacting on the response to K.

Over the three crops the addition of K on its own has added 8.4% (760 kg/ha) extra yield to the crop (Figure 2). In relation to the FR treatments the extra yield increased by another 10% for a total of 1663 kg/ha; however this includes the background nutrition that was also added to these treatments. Overall the response to K has been half of the response to P.

Trial site susceptible to low level lodging at harvest

Sulfur trial

Consistent with previous year's data the S trial showed no response to additional rates of sulfur fertiliser. The only differences of note was that the FR plots were considerably lower than the rest of the trial with a nearly 23% difference between it and the additional S treatments. Also of note was where the background P and K was left out of the treatment then there was a 7-8% drop in yield even though this is classed as not a significant difference within this data set. There was considerable variation between plots due to the hard finish in the season and some plant lodging which was why the LSD was quite high for this trial. It is unknown why there was more variability in the data from the sulfur trial than the other trials at this site.

Table 4. Comparison of mean grain yields across treatments in S trial for sorghum 2016

Label	2015-16	Least significant difference (P=5%)	Relative difference to '0S' plots (kg/ha)	Relative difference to '0S' plots (%)
FR	2494	a	-426	-14.6
0S-PK	2682	ab	-238	-8.2
0S	2921	b	0	0.0
10S	2964	b	43	1.5
20S	2901	ab	-19	-0.7
30S	2929	ab	9	0.3
30S-PK	2709	ab	-211	-7.2

Means with the same letter are not significantly different (l.s.d=423)

None of the last three sorghum crops were responsive to additional sulfur despite the soil test showing less than 3 mg/kg sulfur available in the profile down to 60 cm (Figure 4). This trial data does confirm the role that P and K is playing at this trial site with consistent reductions in yield when the background P and K are left out of the treatment (7-8%). The trial has also consistently shown a major reduction in yield in the FR plots where not only is P and K missing but the supply of nitrogen has also been reduced.

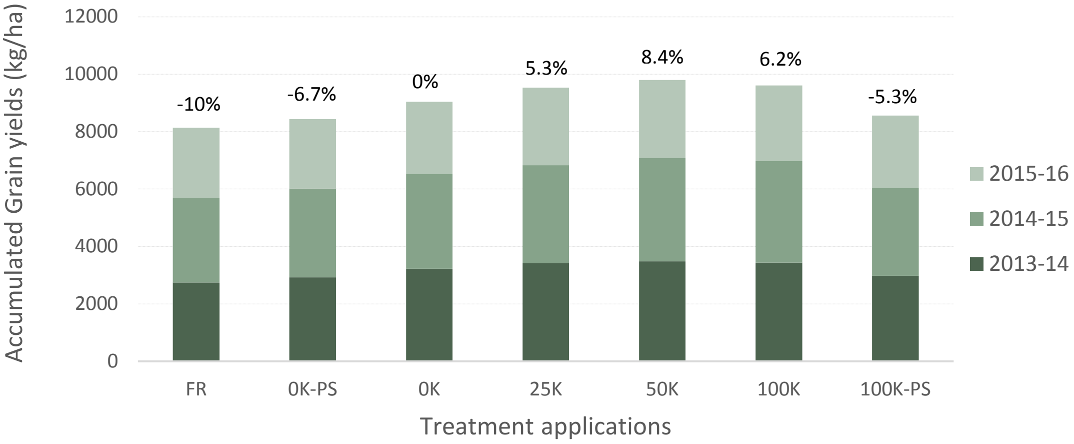


Figure 3. Accumulated grain yields across all K treatments over three successive sorghum crops

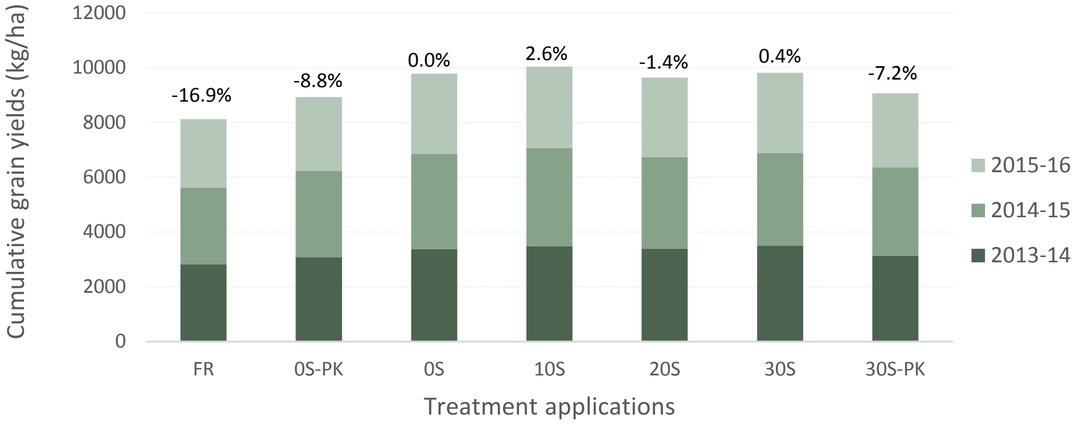


Figure 4. Accumulated grain yields across all S treatments over three successive sorghum crop

Implications for growers

This trial site has demonstrated that when soil tests show very low levels of P (less than 2 mg/kg, 10 to 60 cm), then additional rates of P (20 to 40 kg/ha), placed deep in the profile can give a significant crop response (15% plus) over three consecutive crop years. This is significant given that sorghum is not known as the most responsive species to phosphorus and there has been some variability in the seasonal constraints.

Although K has not shown as bigger difference as P over the last three years, it has shown to add a small but consistent response to crop yield (7-8%). This is proving that one application of deep placed K can continue to be accessed by the plants over at least three years. Responses to K were expected to be bigger at this site given soil test values of 0.12 meq/100g or less (10 to 60 cm), however the complication of the P levels also being in deficit has seemingly overshadowed the K response.

The sulfur response at this site remains a mystery given low soil test values that have traditionally been considered responsive to additional sulfur. Over three years there has been no change in the consistency of this non-response. The complicating factor is that this site has multiple nutrient deficiencies which may or may not be overshadowing sulfur uptake in the plant.

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 UQ 00063 'Regional soil testing guidelines for the northern grains region'.

Trial details

Location:	Dysart
Crop:	Sorghum (MR Taurus)
Soil type:	Grey Vertosol (Brigalow scrub) on minor slopes
In-crop rainfall:	202 mm
Fertiliser:	Urea applied at 100 kg/ha in February 2016 (2 weeks after planting, 0-10 cm); no starter fertiliser applied at planting

Selected soil fertility characteristics for the trial site

Depth (cm)	Nitrates	Sulfur (KCl-40)	Col P	BSES P	Exc. K	ECEC
0-10	2	1.7	5	8	0.25	35.6
10-30	1	1.6	1	3	0.12	28.8
30-60	1	2.6	1	4	0.09	31.4

Trial site at physiological maturity

Sorghum: impact of deep-placed phosphorus and potassium on grain yield—Lundavra, Condamine, Warra and Jimbour West

Dr David Lester[1], Prof Michael Bell[2], Kerry Bell[1] and Michael Mumford[1]

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RESEARCH QUESTIONS: *Does putting phosphorus and potassium (immobile nutrients) in the soil at 15-20 cm deep increase grain yield? How long can crop responses from deep-placed application be detected? How does starter phosphorus interact with deep placed phosphorus?*

Key findings

1. Starter fertiliser had no effect on sorghum yield at three sites where it was applied.
2. Deep placed P increased yields at two sites.
3. Deep placed potassium (K) increased yield on a site with low subsurface K (Warra), but not the second (Jimbour West).

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 the return of crop residue is depositing these immobile nutrients into the surface layer (0–10 cm), 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 and limited in-crop rainfall; 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 deeper than 15 cm can increase grain yield, and if so, over how many cropping seasons.

What was done

Introducing cropping to grazing lands has depleted subsoil (>10 cm) P, with most of the crop P requirement being met by soil reserves in the 10–30 cm layer. Previous research established the concept of deep-placing P for crops in southern Queensland and demonstrated the potential to improve yields using rates of 40 kg P/ha or more. This research is attempting to establish how application rate influences crop response of a range of species and seasonal conditions by following deep-placed P for several crop seasons.

Soil test results from samples collected at experiment establishment confirmed P stratification between surface 0-10 and subsurface 10-30 cm and 30-60 cm depths for all sites (Table 1). Potassium was also stratified in distribution between surface and subsurface layers. Both the Jimbour West and Warra sites exchangeable K (Ex K) of approximately 0.2 cmol/kg below 10 cm, are at the marginal plant available supply level. Background K was

Table 1. Soil test P and K results for deep P sites growing sorghum in 2015-16

Site	Lundavra			Condamine			Jimbour West			Warra		
Depth (cm)	Colwell P	BSES P	Ex K	Colwell P	BSES P	Ex K	Colwell P	BSES P	Ex K	Colwell P	BSES P	Ex K
0-10	17	53	0.71	18	66	1.3	37	97	0.47	14	79	0.40
10-30	5	16	0.47	6	22	0.38	8	12	0.20	3	26	0.22
30-60			0.37	7	17	0.28	4	7	0.22	< 2	18	0.18

applied at Jimbour West (Table 2) when the experiment was established to reduce potential K limitation for crops. Plots at Warra were split into with and without a deep K application in 2015 following two crops at the site that suggested marginal plant K supply from plant tissue analysis.

Each trial had a similar framework of design and implementation. The deep placement treatments occurred from December 2012 through to January 2014 as part of a broader nutrition research program. Fertiliser was applied in bands through tubes on the back of ripper tynes to a depth of 15 to 25 cm, with spacing between bands of 50 cm. Bands were applied perpendicular to the sowing row. Several rates of P were applied ranging from 0 kg P/ha up to 60 or 80 kg P/ha to establish firstly if there was a yield response and secondly if a response occurred, how many crop rotations the response would last for. The zero treatment was ripped as well to eliminate a potential tillage effect. An untilled farmer reference (FR) treatment was included to detect any potential effect of tillage and provide a measure of current production.

At three sites, plots were split into with and without starter-P application (no starter was used at the Warra site). The initial deep placement trials established in late 2012 (such as Lundavra) used triple superphosphate (TSP) as the P source; experiments after this used monoammonium phosphate (MAP). When the deep-placed treatments where applied, additional background applications of sulfur (S), as ammonium sulfate, and zinc (Zn), as zinc oxide were made into the P fertiliser band. Additional nitrogen (N) was added as urea (40 or 60 kg N/ha equivalent) and was separated from the deep P band in a mid-row position (Table 2). The starter-P treatments were applied at planting in the sowing row for each crop. There were six replicates for each treatment.

Grain yield was measured using a plot harvester and grain yield corrected to Graincorp receival standard moisture content.

Results

Grain yield for starter x deep P trials

Grain yield was statistically influenced by deep-P at two sites—Lundavra and Jimbour West (Table 3). While the starter P by deep P interaction was statistically significant at Lundavra, it appears to be a false positive result with plot data inconsistent for one starter x deep P combination (data not shown). The deep P treatment alone was highly significant as the main effect on yields as displayed in Figure 1.

Table 3. Statistical significance for starter or deep P treatments for sorghum trials in 2015-16

Treatment	Lundavra	Condamine	Jimbour West
Starter	NS	NS	NS
Deep-P	$p < 0.001$	NS	$p < 0.01$
Starter x Deep P	$p < 0.05$	NS	NS

NS = not significant ($p > 0.05$)

Grain yield at Lundavra was increased by 740 kg/ha (21%) from the 0 kg P/ha to 80 kg P/ha treatment (Figure 1a). It is uncertain why the 0 kg P/ha yield is lower than the farmer reference (FR) or untreated control in this figure. Possible explanations include tillage to establish the deep treatments reducing soil water, however the tillage occurred three seasons earlier when the experiment was established making this unlikely. Other locations have reported positive impacts from the deep tillage and background (basal) treatments such as Jimbour West (Figure 1c). Grain yield increased up to the 30 kg P/ha treatment, but were relatively small. The deep tillage appears to have overcome some other constraint as the FR treatment is the lowest result.

Table 2. Experimental treatments for deep P sites growing sorghum in 2015-16

Site	Lundavra	Condamine	Jimbour West	Warra
Deep P application	Dec 2012	Dec 2013	Jan 2014	Jul 2013
P Product	TSP	MAP	MAP	MAP
P rates (kg P/ha)	FR, 0, 5, 10, 20, 40, 80	FR, 0, 10, 20, 30, 60	FR, 0, 10, 20, 30, 60	FR, 0, 10, 20, 30, 60
Basal nutrients (kg/ha)	40 N 10 S 0.5 Zn	40 N 10 S 0.5 Zn	60 N 50 K 10 S 0.5 Zn	60 N 100 K (2015) 10 S 0.5 Zn
Site cropping history	Chickpea 2013 Wheat 2014	Wheat 2014	Barley 2014 Mungbean 15-16	Sorghum 13-14 Chickpea 2014

Yields at Condamine (Figure 1b) trended higher with the higher P applications (20 kg P/ha), but are not statistically different. Variation around the yield is higher at Condamine, making it more difficult to establish statistical significance.

These were the third crops at both Lundavra (previously chickpea, then wheat) and Jimbour West (barley then mungbean) sites, and the first at Condamine. Cumulative yield response at Lundavra (Table 4) has only modest increases of 370 kg/ha at 40 kg P/ha and 680 kg/ha at 80 kg P/ha. This contrasts with the results from Jimbour West (Table 5) showing substantial increases in grain yield from 10 kg P/ha upwards.

Table 4. Cumulative grain yield for three crops at Lundavra from deep-placed P rates

Treatment (kg P/ha)	FR	0	5	10	20	40	80
Grain yield (kg/ha)	9860	9726	10006	10068	10016	10231	10537

Table 5. Cumulative grain yield for three crops at Jimbour West from deep-placed P rates

Treatment (kg P/ha)	FR	0	10	20	30	60
Grain yield (kg/ha)	7098	7690	8046	8345	8388	8625

Grain yield for deep P +/- K trial

Grain yield was significantly influenced by P rate ($p<0.05$) or K rate ($p<0.01$), but not the interaction P x K. The 60 kg P/ha treatment was 600 kg/ha higher than 0P (Figure 2a) while applying 100 kg K/ha increased yield by 375 kg/ha compared to 0 kg K/ha (Figure 2b). Other experiments with both low P and K (typically in Central Queensland) don't often record a K only response. Usually responses to K are only measured after P has been applied. While this was the third crop on the deep P trial at this site, it was the first following the deep K application. Crop responses in the first two crops were most likely K limited and so a cumulative grain yield will not be an accurate assessment.

Implications for growers

Earlier deep placements of P generally increased yields for sorghum at sites in 2015-16. Soil test K is also worth monitoring in the profile, with responses possible when soil test values in the >10 cm layers are less than 0.2 cmol/kg. While the response to P 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. The Lundavra and Warra sites were double-cropped to chickpea in 2016 and results will be reported in the coming year. Cumulative production at two sites is demonstrating contrasting responses to deep placement. The Jimbour West site has increased cumulative response by over 1300 kg/ha from three crops (barley, mungbean, sorghum) with 20 kg P/ha, while the Lundavra experiment has smaller increases using larger application rates (up to 80 kg P/ha). The reasons for this are currently under investigation.

Grain yield impact of starter application in these trials was not significant, but the application of starter fertiliser can provide other management and agronomic benefits and should be continued.

Further research is required to accurately answer the question how much and how often should deep-P be applied.

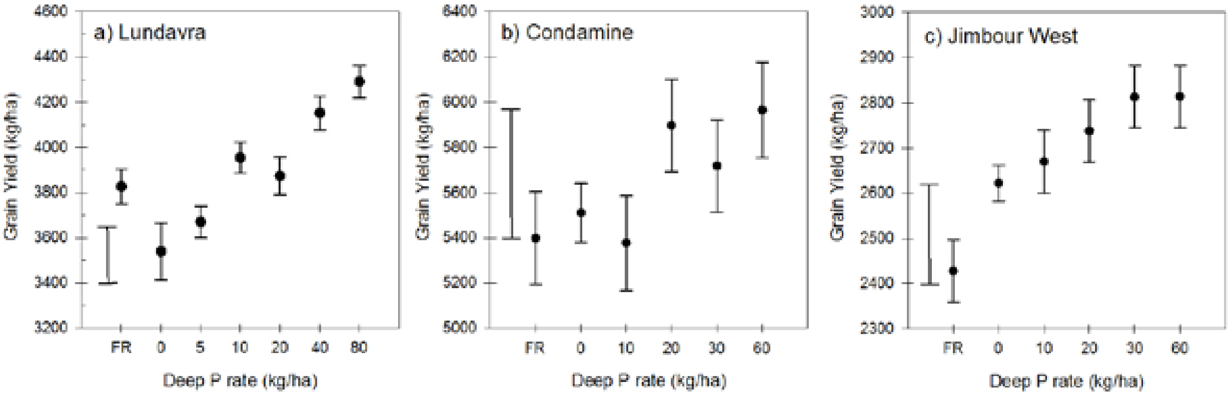

Figure 1. Sorghum grain yield (kg/ha) from deep-placed P sites at a) Lundavra, b) Condamine and c) Jimbour West grown in 2015-16. Error bar is lsd at 5%

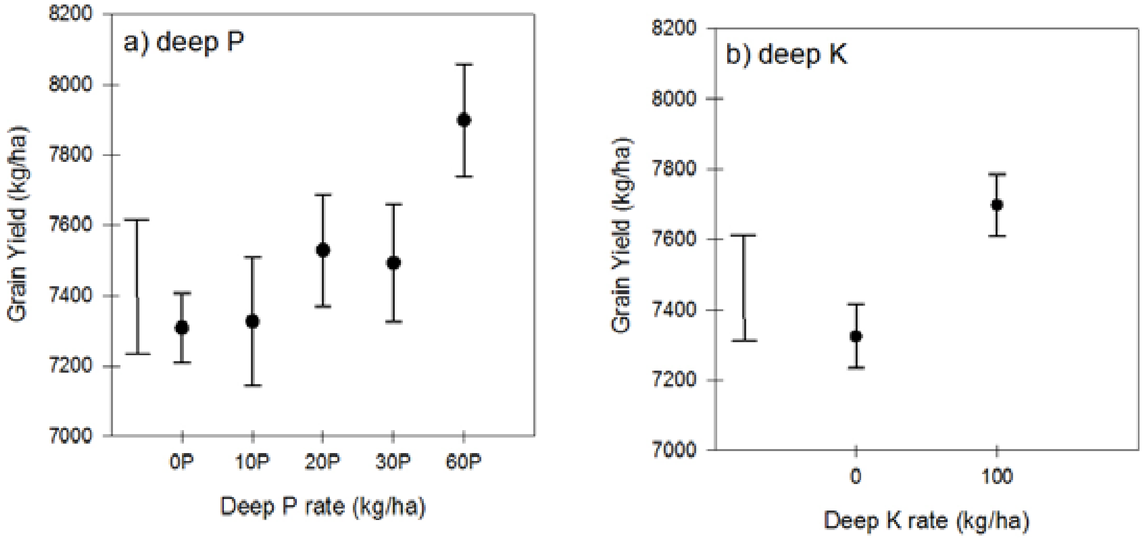

Figure 2. Sorghum grain yield (kg/ha) at Warra from deep-placed a) P and b) K grown in 2015-16. Error bar is lsd at 5%

Acknowledgements

This work is funded by the Grains Research and Development Corporation and the Department if Agriculture and Fisheries under UQ00063 'Regional soil testing guidelines for the northern grains region'. The hosting of the sites by the grower co-operators is gratefully acknowledged.

Soil sampling during experiment set up at Condamine in February 2014

Trial details

Agronomic details for sorghum trials in 2015-16 season

Site	Lundavra	Condamine	Jimbour West	Warra
Date sown	2-Nov-15	10-Sep-15	13-Jan-16	8-Sep-15
Variety	MR43	Dominator	MR-Taurus	MR43
Row spacing	Double-skip	1 m solid	1 m solid	0.5 m solid
Population	45000 (sown)	60000 (pop)	70000 (sown)	45000 (sown)
Starter product	MAP + Zn	Starter-Z	Supreme-Z	None
Starter rate	20 kg/ha	20 kg/ha	40 kg/ha	
Maturity biomass date	25-Feb-16	21-Jan-16	14-Apr-16	2-Jan-16
Harvest date	25-Feb-16	22-Jan-16	16-May-16	13-Jan-16
Soil type	Grey Vertosol	Grey Vertosol	Brown Vertosol	Grey Vertosol
In-crop rainfall	241	220	247	215

Sorghum: potassium effects on grain—Jimbour West and Chelmsford

Dr David Lester[1], Prof Michael Bell[2], Kerry Bell[1] and Michael Mumford[1]

[1] Department of Agriculture and Fisheries
[2] University of Queensland

***Research Question:** For soil with low subsoil potassium, does applying potassium at 15-20 cm deep in the soil, either with or without phosphorus, increase grain yields?*

Key findings

1. Treatments with potassium and/or phosphorus had no effect on grain yield at either location in 2015-16.

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 by plants from the soil in the 0.1-0.3 m layer. Return of crop residue is depositing potassium onto the surface. 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 and limited in-crop rainfall. Potentially 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 deeper into the soil increase grain yield.

What was done

Soil testing confirmed both K and P stratification between surface 0-0.1 and subsurface 10-30 cm/30-60 cm depths for all sites (Table 1). Potassium is marginal for both the Chelmsford and Jimbour West sites with exchangeable K of approximately 0.2 cmol/kg below 10 cm.

Table 1. Soil test P and K results for deep P sites growing sorghum in 2015-16

Site	Chelmsford*			Jimbour West		
Depth	Col P	BSES P	Ex K	Col P	BSES P	Ex K
0-10 cm	16	12	0.21	37	97	0.47
10-30 cm	2	4	0.14	8	12	0.20
30-60 cm	< 2	3	0.12	4	7	0.22

* samples collected in August 2013; Site had 10 t/ha feedlot manure June 2015

Potassium and phosphorus rates are show in Table 2. Treatments are applied at a depth of roughly 20 cm, with fertiliser bands spaced 50 cm apart. Fertiliser is parallel with sowing direction at Chelmsford and perpendicular at Jimbour West. Sulfur (S), as ammonium sulfate and zinc (Zn), as zinc oxide applications were made into the fertiliser trench with the P application. At Jimbour West, urea was applied to balance the nitrogen input to 40 kg N/ha through a tyne positioned between the bands of deep P. Chelmsford had five replicates, Jimbour West six.

Table 2. Experimental treatments for deep K sites growing sorghum in 2015-16

Chelmsford treatments – established August 2013							
Trt no	1	2	3	4	5	6	
K rate (as Potassium Chloride)	0	100	0	25	50	100	
P rate (as Triple Super Phosphate)	0	0	20	20	20	20	
Jimbour West treatments – established January 2014							
Trt no	1	2	3	4	5	6	7
K rate (as Potassium Chloride)	0	100	0	25	50	100	FR
P rate (as Mono Ammonium Phosphate)	0	0	20	20	20	20	FR

Crop management and agronomic management for the site are detailed in Table 3. Above ground biomass was measured at maturity. Grain yield was measured using a plot harvester and grain yield corrected to Graincorp receival standard moisture content. Statistical analysis was conducted using ASREML in Genstat.

Table 3. Agronomic details for sorghum trials in 2015-16 season

Site	Chelmsford	Jimbour West
Date Sown	1-Nov-15	13-Jan-16
Variety	MR Buster	Taurus
Row spacing	0.9 m solid	1 m solid
Population	70000 (sown)	70000 (sown)
Starter product	None	Supreme-Z
Starter rate		40 kg/ha
Maturity biomass date	9-Mar-16	14-Apr-16
Harvest date	05-Apr-16	16-May-16
In-crop rainfall		247

Results

No treatment at either site had any significant influence on grain yield ($p > 0.05$). Chelmsford (Figure 1a) had very high grain yield for dryland conditions. Jimbour West (Figure 1b) suggested higher yields with P application and then higher K application rates (50/100 kg K/ha) but none were statistically significant.

At Chelmsford, there was no significant effect on dry matter at maturity (mean 16000 kg/ha) or K uptake (mean 162 kg K/ha). Wetter than normal seasonal conditions allowed the crop to access surface K supplies (and the applied feedlot manure) so no effect of the deep-placed treatments was recorded.

Jimbour West had no significant effect on dry matter (mean 8600 kg/ha) but K uptake in dry matter was increased by K treatment, rising from 69 kg/ha in Farmer Reference (FR) to 90 kg/ha in the 100 kg K/ha plus P treatment. The crop was sown late and yielded relatively poorly for the available moisture, so the limited crop K demand was able to be met (just) by the background soil supplies.

Implications for growers

Potassium application has increased grain yields at these sites in previous years, however seasonal conditions in 2015-16 provided no responses to deep placement of K and/or P. When growing season conditions are favourable, as in the 2015/16 season, crops may be able to acquire more nutrient in the surface enriched layers.

Acknowledgements

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'. The hosting of these sites by the grower or co-operators is gratefully acknowledged.

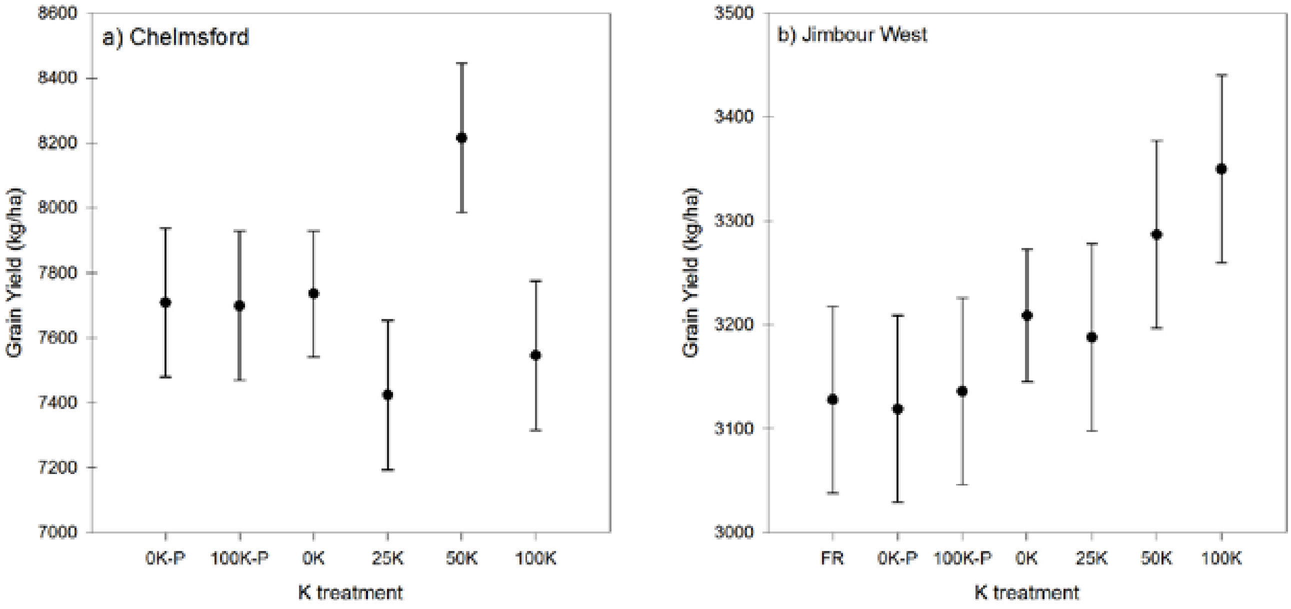

Figure 1. Sorghum grain yield (kg/ha) from deep-placed K treatments at a) Chelmsford and b) Jimbour West grown in 2015-16. Error bar are standard error for each mean

Sunflower: no impact on growth or seed yield with sulfur fertiliser—Darling Downs

Dr David Lester[1], Prof Michael Bell[2] and Kerry Bell[1]

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[2] University of Queensland

RESEARCH QUESTION: *Is sulfur limiting grain yields on the Darling Downs?*

Key findings

1. Sulfur application rate had no effect on crop growth.
2. Sulfur application rate had no effect on sulfur status of biomass or seed yield.

Background

Sulfur (S) is one of the key nutrients necessary for crop growth. Research in Queensland has demonstrated responses to sulfur are often only present after the crop has met its requirement for nitrogen (N), phosphorus (P) and potassium (K). The amount of organic matter in cropping soil has declined as cropping has continued resulting in a loss of organic N and S from the soil nutrient pool. Sulfur availability from the organic pool is similar to N; as organic matter mineralises these nutrients are released in an 'available' form suitable for soil microbes and crops to utilise. Available sulfur can also be present in higher concentrations down the soil profile often below 60 cm (typically as natural gypsum or due to leaching), but roots have to grow to be at this depth to utilise this source. As a result, crop responses to sulfur fertiliser appear to be more likely under the following scenarios:

1. the mineralisation of plant available sulfur from organic matter is either low (e.g. during winter) or has a limited time period to occur such as higher cropping intensity (double-cropping), particularly from summer into winter crops
2. root access to available sulfur at depth is restricted; typically by better than average rainfall not requiring the crop to forage further into the soil profile

What was done

The experiment was located on the eastern Darling Downs in the Irongate district, on a black vertosol with relatively high P and K availability (Table 1). Sulfur treatments were applied at 0 (x2), 5, 10, 20 and 40 kg S/ha as ammonium sulfate (21% N 24% S) in September 2014 prior to a grain sorghum crop in 2014-15 (refer 2015 trial book). To ensure N was not limiting, total applied N was increased to 120 kg/ha for all plots using urea (46% N). With other macronutrients plentiful, it was hoped that S alone could be explored as the sole nutrient constraint. There were six replicates, making 36 plots in total.

Table 1. Selected soil fertility characteristics

Depth (cm)	Colwell P	BSES P	Exchange-able K	Effective Cation Exchange Capacity	MCP-S
0-10	52	164	2.05	65	6.0
10-30	12	210	0.88	68	4.8
30-60	4	210	00.83	67	3.3

Following sorghum (*Sorghum bicolor*) in the 2014-15 cropping season and a fallow period over winter, NuSeed "Ausistripe 14" sunflower (*Helianthus annuus*) was sown at 55,000 seeds/ha on 26 August 2015 using an airseeder at a 75 cm row spacing. Yara Flowphos 13Z (9% N, 13%P, 1%K, 0.9% Zinc) at 20 L/ha was applied in the seed row at sowing.

Growing season rainfall was excellent (Figure 1) providing very good seasonal growing conditions over the 137 day period from sowing to harvest.

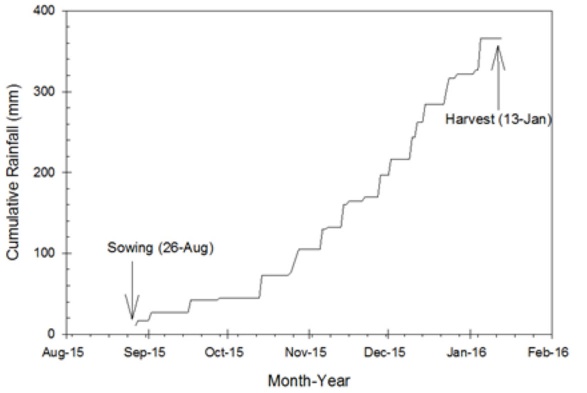

Figure 1. Cumulative rainfall (mm) at Irongate during 2015-16 growing season

Above ground biomass was collected at maturity on 13 January 2016 from a selection of treatments to characterise the plant response. Plants were cut at ground level from 2 m of row. Following drying, weighing and grinding, the plant sample was analysed for nutrient concentrations including N and S. Grain yield was measured using a plot harvester on 13 January 2016, and grain yield results were corrected to the depot receival moisture. Seed samples collected at harvest were ground and sent for the same chemical analysis as the maturity biomass sample.

Sulfur uptake in above ground dry matter (kg S/ha) was calculated as the above ground dry matter (kg/ha) x dry matter S concentration (%). S removed in seed (kg S/ha) was calculated as moisture corrected seed yield (kg/ha) x seed S concentration (%).

Results

Sulfur rate had no significant effect (p>0.05) on dry matter at maturity (Figure 2a, mean 11,010 kg/ha), whole plant sulfur concentration (Figure 2b, mean 1390 mg/kg), or plant sulfur uptake (Figure 2c, mean 15.3 kg S/ha).

These results highlight two main difficulties with researching sulfur:

1. getting biomass data that represents the treatment effect with high precision, and
2. accounting for the recovery of fertiliser S by the crop using the difference method, which compares S concentration and uptake in a control plot against treated rates.

Plant number in the biomass sample area ranged from 4-14 plants, highlighting variability in establishment across the trial area from the airseeder. Using a precision planter for summer crops on wider rows should improve the spatial plant arrangement and offer higher yield potential. In future research with similar crop establishment methods, increasing the sample area (to cut more rows or longer length of row) may improve the measurement of biomass growth.

Seed yield also was not influenced by S rate (Figure 3a) with site average yields of 3080 kg/ha. Increasing the number of replicates, or the number of grain yield measurements per plot are additional field options to improve precision of yield measurement in future trials.

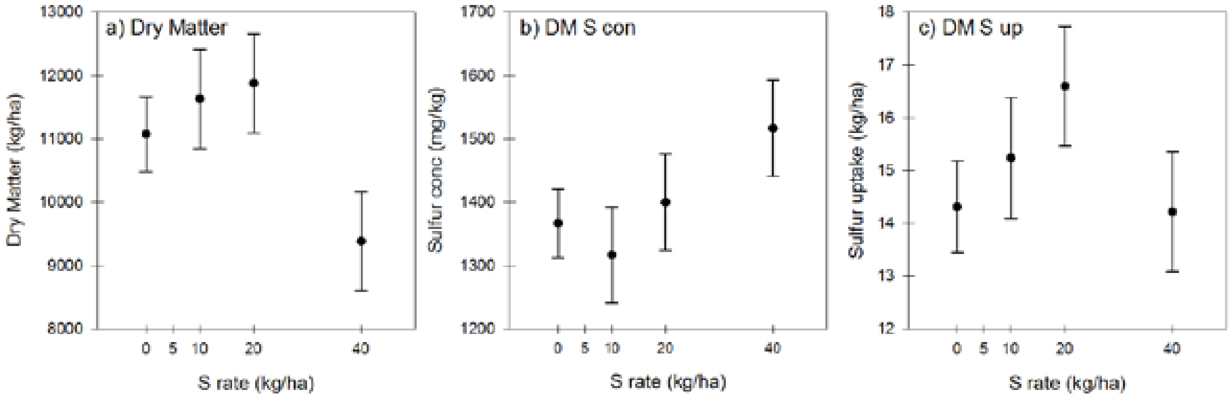

Figure 2. Effect of S rate (kg/ha) on a) sunflower dry matter at maturity, b) sulfur concentration in whole tops, and c) sulfur uptake. There is no statistical signifance for any of these measurments

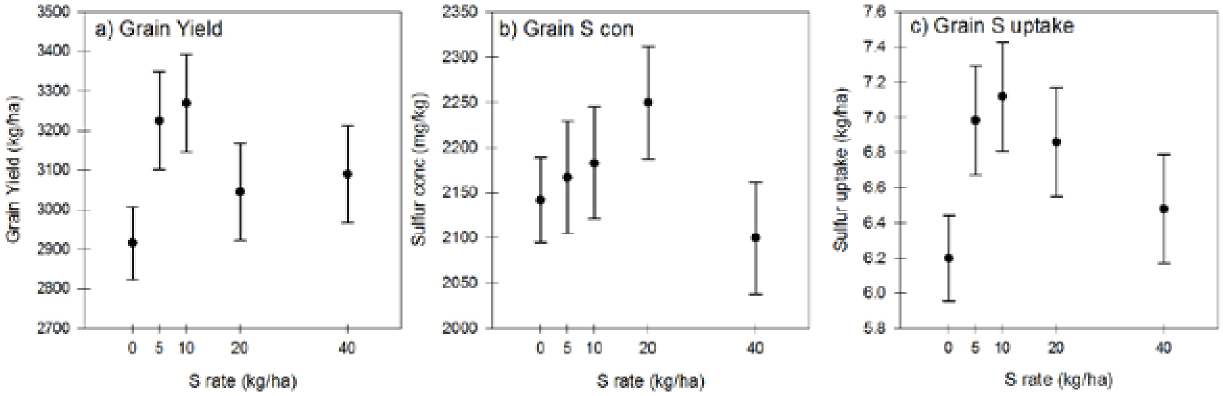

Figure 3. Effect of S rate (kg/ha) on a) sunflower grain yield, b) sulfur concentration in grain, and c) sulfur export in grain. There is no statistical signifance for any of these measurments

Grain S concentration (Figure 3b) although appearing to trend upwards until the 20 kg S/ha rate, does not have any significant differences. The lack of treatment influence on seed S concentration indicates that S removal in seed is driven by yield (Figure 3c).

Implications for growers

While there was no effect of sulfur application on grain yield of this sunflower crop, growers are still advised to be cautious of potential sulfur deficiencies primarily under high intensity double cropping situations from summer crops into winter cereals. An adjacent site demonstrated a small grain yield (250 kg/ha) increase in barely double cropped from sorghum. Sulfur experiments have consistently been non-responsive to S rate for longer fallow lengths.

Acknowledgements

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’. The support of the site host is gratefully acknowledged.

Trial details

Location:	Irongate
Crop:	Ausistripe 14 sunflower
Soil type:	Black Vertosol
Fertiliser:	Sulfur treatments were applied at 0 (x2), 5, 10, 20 and 40 kg S/ha as ammonium sulfate (21% N 24% S) in September 2014 , total applied N was increased to 120 kg/ha for all plots using urea (46% N)

Sunflower head from sulfur trial 2015-16

Chickpea: no responses to starter and deep phosphorus—Roma, Lundavra, Westmar and Warra

Dr David Lester[1], Douglas Lush[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 0.2 m deep increase grain yields? How does starter phosphorus interact with deep placed phosphorus?*

Key findings

1. Neither starter nor deep placed phosphorus treatment had any effect on grain yield.
2. Whole plant phosphorus concentration increased with deep phosphorus rate.
3. Grain phosphorus removal was generally 3.0-3.5 kg P/t

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 by plants from the soil in the 10-30 cm layer. Return of crop residue is depositing these nutrients back onto the soil surface, 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 and limited in-crop rainfall so plants have limited opportunity to acquire nutrient in the enriched layer. Potentially 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 deeper into the soil increase grain yield.

What was done

Selected chemical fertility results confirm P stratification between surface 0-10 cm and subsurface 10-30/30-60 cm depths for all sites (Table 1).

Each trial had a similar framework of design and implementation. The deep placement treatments were P fertiliser bands applied at a depth of ≈ 20 cm. These fertiliser bands were spaced 50 cm apart perpendicular to the sowing row. Each deep P plot was set up so that a starter P application could be applied to one side and not the other. The starter P treatments were applied at planting by the co-operator using their choice of product and rate. Additional basal applications of sulfur (S), as ammonium sulfate and zinc (Zn), as zinc oxide were made into the fertiliser trench with the P application. Additional nitrogen was added (40 or 60 kg N/ha equivalent) in the form of urea through a tyne that was position between the bands of deep P. Potassium is marginal for the Warra site with an exchangeable K of approximately 0.2 cmol/kg below 10 cm (Table 1). Plots at Warra where split into with/without a deep K application in 2015 following two crops (sorghum 2013-14 and chickpea 2014) at the site that suggested marginal plant K supply from plant tissue analysis. Summaries of nutrient application are in Table 2.

Table 1. Soil test P and K results for deep P sites growing chickpea in 2016

Site	Mt Bindango Sth			Lundavra			Westmar			Warra		
	Col P	BSES P	Ex K	Col P	BSES P	Ex K	Col P	BSES P	Ex K	Col P	BSES P	Ex K
0-10 cm	20	46	1.18	17	53	0.71	16	52	1.14	14	79	0.40
10-30 cm	5	28	0.69	5	16	0.47	2	12	0.52	3	26	0.22
30-60 cm	2	27	0.64			0.37				< 2	18	0.18

Table 2. Experimental treatments for deep P sites growing sorghum in 2015-16

Site	Mt Bindango Sth	Lundavra	Westmar	Warra
Date deep P treatment	Dec 2015	Dec 2012	Dec 2012	Jul 2013
P Product	MAP	TSP	TSP	MAP
P rates (kg P/ha)	FR, 0, 10, 20, 30, 40, 60	FR, 0, 5, 10, 20, 40, 80	FR, 0, 5, 10, 20, 40, 80	FR, 0, 10, 20, 30, 60
Basal nutrients	40 kg N/ha 2.0 kg Zn/ha	40 kg N/ha 10 kg S/ha 0.5 kg Zn/ha	40 kg N/ha 10 kg S/ha 0.5 kg Zn/ha	60 kg N/ha 100 kg K/ha (2015) 10 kg S/ha 0.5 kg Zn/ha
Site cropping history		Chickpea 2013 Wheat 2014 Sorghum 15-16	Chickpea 2013 Wheat 2014 Chickpea 2015	Sorghum 13-14 Chickpea 2014 Sorghum 15-16

Table 3. Agronomic details for chickpea trials in 2016

Site	Mt Bindango Sth	Lundavra	Westmar	Warra
Date Sown	22-May-16 (moisture seeking)	14-Jun-16	15-May-16 (moisture seeking)	15-Jun-16
Variety	Kyabra	HatTrick	HatTrick	Boundary
Row spacing	0.75/1.00 m	0.33 m	0.33 m (2 in: 1 out)	0.50 m solid
Population	65 kg/ha sown	50 kg/ha sown	65 kg/ha sown	55 kg/ha sown
Starter product	SupReme-Z	MAP+Zn	13Z	None
Starter rate	35 kg/ha	20 kg/ha	20 L/ha	
Maturity biomass date	26-Oct-16	10-Nov-16	01-Nov-16	27-Oct-16
Harvest date		16-Nov-16	15-Nov-16	15-Nov-16
In-crop rainfall	296 mm	293 mm		253 mm

There were six replicates used with eight treatments (2 x 0 plots used to get 8 treatments) in each, making a total of 96 plots in each trial. Three replicates at the Mt Bindango South site were unable to be used this season.

Crop management and agronomic management for the site are detailed in Table 3. Two sites (Mt Bindango South and Westmar) were sown deep into moisture, while the remaining sites were sown shallow following rain. Above ground biomass was measured at maturity. Grain yield was measured using a plot harvester and grain yield corrected to Graincorp receival standard moisture content. Statistical analysis was conducted using ASREML in Genstat.

Results

There were no significant effects of starter P, deep P, or interactions between P placement strategies (p› 0.05) on grain yield at any of the four sites (Figure 1). Yields at Mt Bindango

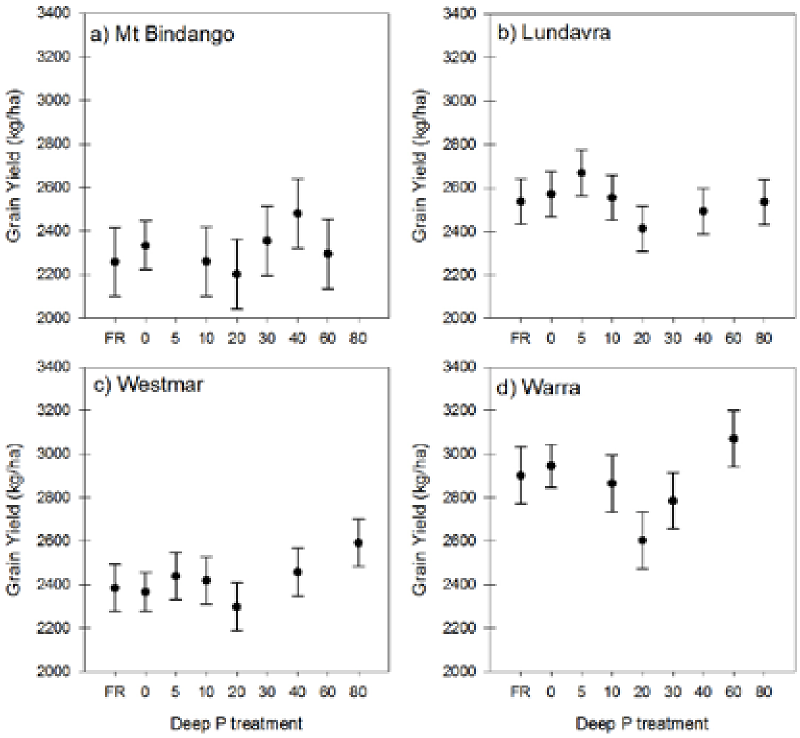

Figure 1. Chickpea grain yield (kg/ha) from deep placed P treatments at a) Mt Bindango South, b) Lundavra, c) Westmar and d) Warra in 2016. Error bars are standard error for each mean

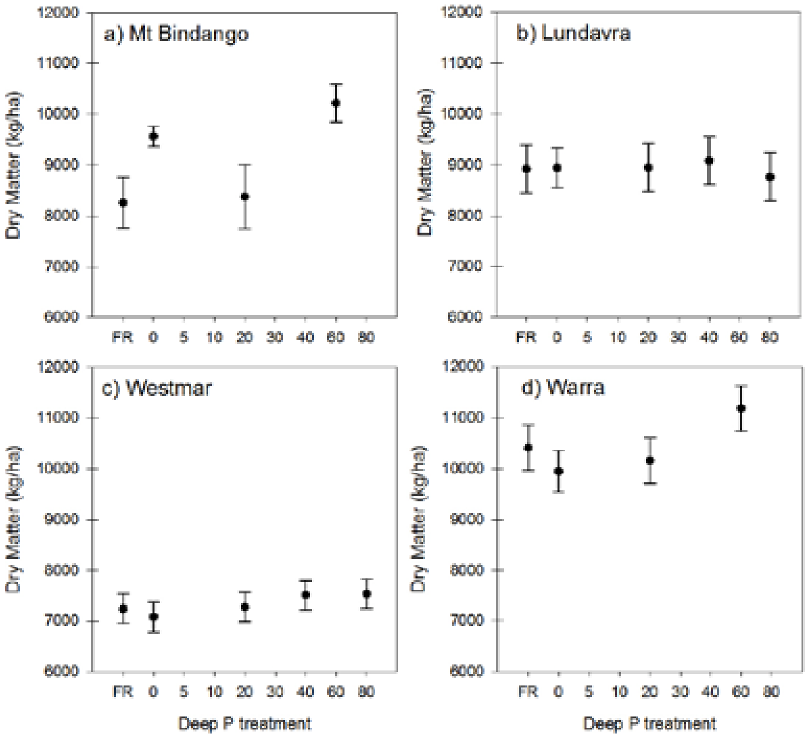

Figure 2. Chickpea dry matter at maturity (kg/ha) from deep-placed P treatments at a) Mt Bindango South, b) Lundavra, c) Westmar and d) Warra in 2016. Error bar are standard error for each mean

(Figure 1a), Lundavra (Figure 1b) and Westmar (Figure 1c) ranged between 2200 and 2600 kg/ha for all treatments, while the Warra yields were higher at 2800 to 3000 kg/ha (Figure 1d).

The consistency of yield at all sites suggests another factor, possibly rainfall-related, may have determined grain yield for this season. Further analysis of weather station data from all sites may enable the development of a hypothesis to this effect.

Above ground dry matter at maturity was also unaffected by P treatment (either starter or deep P) for all sites (Figure 2), although several sites did show early season growth responses with deep P application.

Phosphorus concentration in dry matter increased with deep P treatment at all sites ($p < 0.05$) suggesting plants were accessing the nutrient bands. Mt Bindango (Figure 3a) showed the largest increase in concentration of 400 mg/kg from FR to 60 kg P/ha. Lundavra (Figure 3b) and Westmar (Figure 3c) increased by 150 mg/kg from the FR to 20 kg P/ha or greater rates.

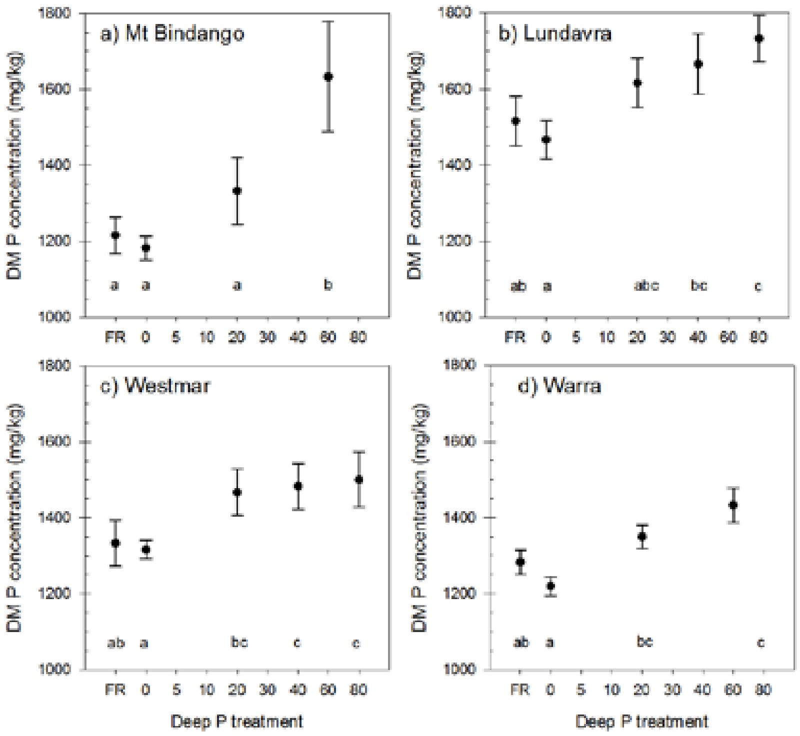

Figure 3. Chickpea P concentration in dry matter at maturity (mg/kg) from deep-placed P treatments at a) Mt Bindango South, b) Lundavra, c) Westmar and d) Warra in 2016. Error bar are standard error for each mean. Letters indicated lsd at 5%

All the sites had similar Colwell P concentrations in the surface and subsurface layers, with the differences in P concentrations between sites for the FR and 0P treatments (from 1200-1600 mg/kg) suggesting differing degrees of exploitation of P in those shallow profile layers in what was a fairly wet season in all except the Warra site.

Grain P concentration was also increased with deep P treatment at all sites ($p < 0.05$). Mt Bindango (Figure 4a) again had the largest change in grain P concentration from FR to 60 kg P/ha. Lundavra (Figure 4b) and Westmar (Figure 4c) showed differences between treatments without P (FR, 0P) and those with deep P at rates of 20 kg P/ha or greater. The reason for the very high P concentrations in the Lundavra grain samples are unknown, but suggest high plant P status consistent with the biomass P data.

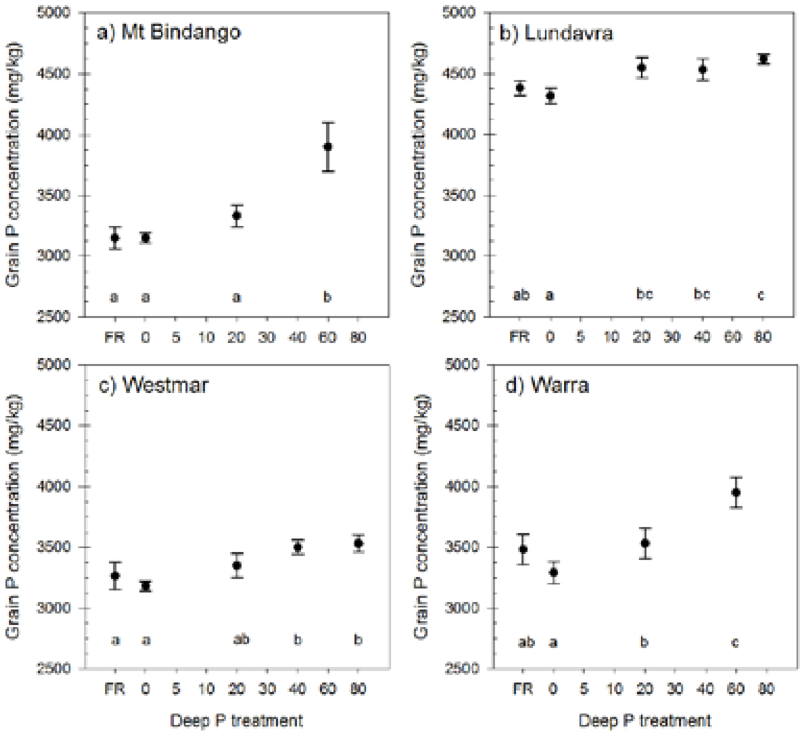

Figure 4. Grain P concentration (mg/kg) of chickpeas grown at a) Mt Bindango South, b) Lundavra, c) Westmar and d) Warra in 2016. Error bar are standard error for each mean. Letters indicated lsd at 5%

Phosphorus harvest index (the ratio of grain P removed to total P uptake) was around 0.7 for Lundavra and Westmar; that translates to 70% of all the P the crop took up, left the field in grain. At Mt Bindango the PHI was 0.7 for the FR and 0P treatments, decreasing to 0.6 at 20 P and 0.5 at 60 P. These high proportions of P removed in grain have significant implications for P recycling in residues and resulting enrichment of surface soil layers. The PHI in grain crops is typically much lower than for these chickpea crops.

Implications for growers

Deep P application has had no effect on grain yield in southern Queensland in 2016. This contrasts with results from CQ where grain yield increases have been substantial, but the unusually wet season with prolonged access to the top 10 cm layer may have been a contributing factor. Further work to understand the physiology of chickpea yield accumulation and the impact of inadequate P nutrition is required.

Grain P removal generally was 3-3.5 kg P/t (3000-3500 mg/kg), apart from Lundavra where it was closer to 4.5 kg P/t.

Acknowledgements

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

The support of the site host is gratefully acknowledged.

Wheat: response to both starter and deep phosphorus—Roma

Dr David Lester[1], Douglas Lush[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 wheat grain yields? How does starter phosphorus interact with deep placed phosphorus?*

Key findings

1. Starter increased yield by 260 kg/ha (5%).
2. Deep placed P treatment (tillage, P and basal nutrients) increased yield by 800 kg/ha (20%).

Background

As the length of time we have been cropping land increases, immobile nutrients such as phosphorus (P) are being taken up by plants from the soil in the 10-30 cm layer. Return of crop residue is depositing these immobile nutrients onto the surface. 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 and limited in-crop rainfall. Potentially 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 deeper into the soil increase grain yield.

What was done

Plant available P is stratified between the surface 0-10 cm and subsurface 10-30/30-60 cm depths (Table 1). Electrical conductivity increases at depth with a significant gypsum layer present below 30 cm. Chloride concentrations are not limiting for root growth in the 1.2 m profile analysed (data not shown).

Nutrient application rates are shown in Table 2. Treatments were applied at a depth of roughly 20 cm, with fertiliser bands spaced 50 cm apart. Fertiliser was perpendicular to sowing direction. A basal Zinc (Zn) was made into the P fertiliser trench. Urea was applied to balance the nitrogen (N) input to 40 kg N/ha through a tyne positioned between the bands of deep P. Deep P plots are split so that a starter P application can be applied to one side and not the other by growers at sowing. Farmer reference (FR) represents grower practice for product and rate for the starter P treatment. There are six replicates in the experiment.

Crop management and agronomic management for the site are detailed in Table 3. Above ground biomass was measured at maturity. Grain yield was measured using a plot harvester and grain yield corrected to Graincorp receival standard moisture content. Statistical analysis was conducted using ASREML in Genstat.

Table 1. Soil test for Mt Bindango North deep placed P site

	pH CaCl2	EC 1:5	Col P	BSES P	Ca	Mg	K	Na
0-10 cm	6.9	0.08	19	48	21.9	7.2	1.14	0.67
10-30 cm	7.2	1.36	3	16	27.1	7.9	0.49	1.34
30-60 cm	6.9	2.08	< 2	18	31.1	8.3	0.47	2.24

Calcium (Ca); magnesium (Mg); Potassium (K); sodium (Na)

Table 2. Experimental treatments for Mt Bindango North deep placed P site (established December 2015)

Treatment	1	2	3	4	5	6	7	8
P rate (as Mono Ammonium Phosphate)	FR	0	0	10	20	30	40	60
N rate (from MAP and Urea)	-	40	40	40	40	40	40	40
Zn rate (Zinc Chelate)	-	2.0	2.0	2.0	2.0	2.0	2.0	2.0

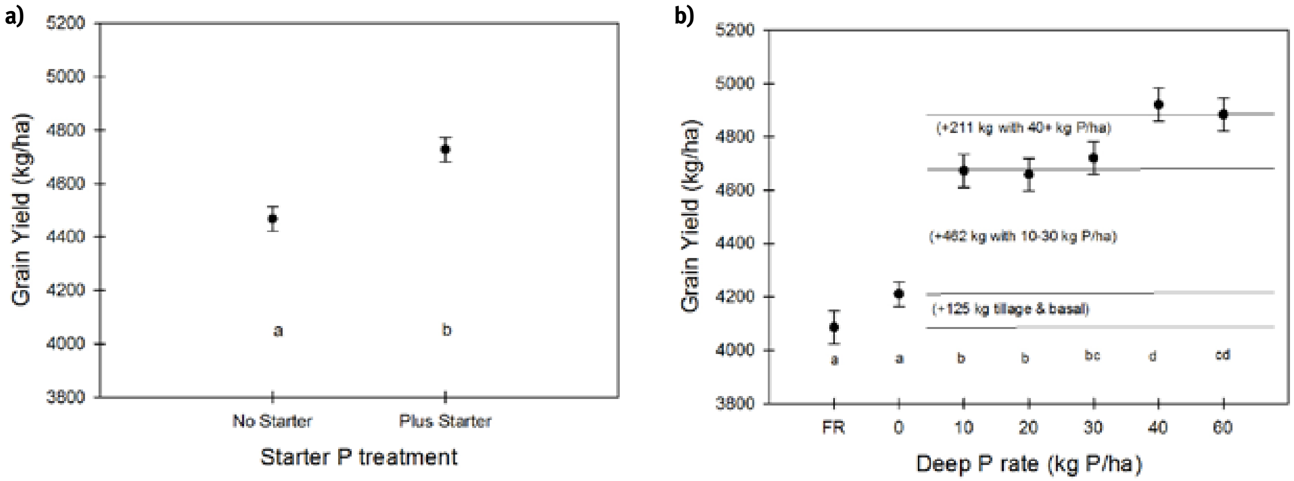


Figure 1. Wheat grain yield (kg/ha) from a) starter applied and b) deep-placed P treatments at Mt Bindango North in 2016. Error bars are standard error for each mean. Letters indicate lsd at 5%

Table 3. Agronomic details for sorghum trials in 2015-16 season

Site	Mt Bindango North
Date Sown	18-Jun-16
Variety	Ventura$^{\text{(D)}}$
Row spacing	50 cm
Population	60 kg/ha sown
Starter product	Granulock Z® at 48 kg/ha
Maturity biomass date	26 Oct 16
Harvest date	03 Nov 16
In-crop rainfall	NA

Results

Both starter ($p<0.001$) and deep-placed treatments ($p<0.001$) significantly increased grain yield. There was no significant interaction between starter and deep treatment ($p>0.05$). Not applying starter decreased yield by 260 kg/ha (Figure 1a). This result is averaged over all treatments; however the effect is still present if just the FR and 0P treatments are analysed as a subset (data not shown). More substantial is the combination effects from the deep-placed P treatments (Figure 1b). Tillage and basal nutrient application did not significantly increase yield on their own (+125 kg), but applying 10-30 kg P/ha at depth increased yield by 587 kg/ha (125 + 462). Further yield increases at higher P rates (40+ kg P/ha) were also observed.

Increased grain yield was due to having grown a bigger plant (Figure 2) with deep P application significantly increasing the biomass at maturity.

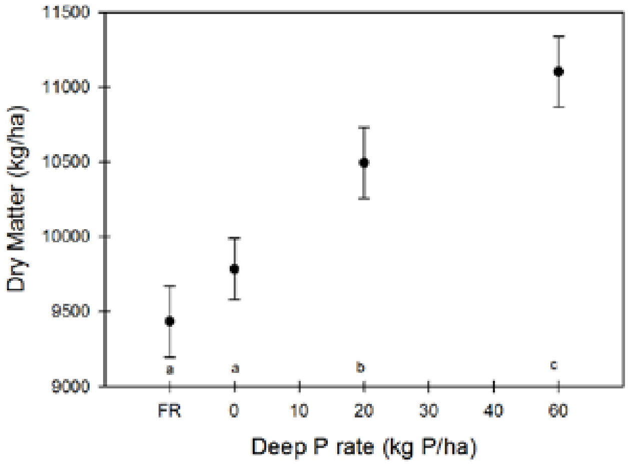


Figure 2. Wheat dry matter at maturity (kg/ha) from deep-placed P treatments at Mt Bindango North in 2016. Error bars are standard error for each mean. Letters indicate lsd at 5%

Implications for growers

Applying P either as starter application, or deep-placed in the profile has increased grain yields in a growing season with above average rainfall. This is the first year of data obtained from this site and future responses will be monitored. Increased grain yield will have implications for nitrogen management, with higher yields requiring a greater nitrogen supply.

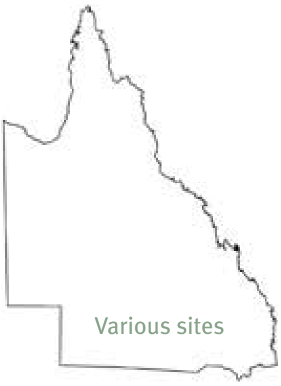
Acknowledgements

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

The economics of deep placement of phosphorus in Queensland and northern NSW

James Hagan, Dr David Lester and Dr Andrew Zull

Department of Agriculture and Fisheries



RESEARCH QUESTION: *Has the deep placement of phosphorus provided economic benefits in trials conducted across Queensland and northern NSW?*

Key findings

1. There were yield increases of 10% or more in 21 of 44 site observations, whilst 30 of 44 observations had responses of 5% or more to 20 kg P/ha.
2. There does not appear to be significant differences in response to phosphorus rates.
3. The majority of 20 kg P/ha treatments would return a profit within two years, if there were no other constraints.

Background

Phosphorus (P) requirements for early crop development are well known for Queensland and northern New South Wales' cropping soils, with critical limits defined and the use of starter P fertilisers well adopted. However, subsoil P requirements are not so readily understood.

Later season P has traditionally come from native subsoil P reserves, but as we deplete this P over years of cropping the need to introduce fertiliser sources to replenish these reserves is becoming more urgent, as stratification occurs.

Nutrient stratification occurs when there is a redistribution of non-mobile nutrients such as P 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. This is an increasing issue across this region.

Table 1. Critical P values and their relationship to P fertiliser decisions in northern vertosols

Do I need to apply deep-P? (10-30cm depth)		
Colwell P	BSES P	Fertiliser decision
>10 mg/kg	NA	No
<10 mg/kg	30-100 mg/kg	Possibly
<10 mg/kg	<30 mg/kg	Highly Likely

The values shown in Table 1 are the estimated subsoil P critical limits required for vertosols in central and southern Queensland and northern New South Wales prior to trials and case studies being commenced. (Bell, 2014)

As P is an immobile nutrient replacing it in this subsoil layer requires it to be either placed into the subsoil or moved there mechanically after being placed on the surface. In order to be integrated with current no-till farming systems it was decided placing the nutrients at depth via less intensive tillage would be the preferable method of application and more likely to be adopted by growers. We refer to this technology as 'deep-P'.

Crop nutrient decisions have traditionally been short-term decisions where the costs and benefits from applied fertiliser are realised within the same cropping season; in contrast deep-P placement is a longer-term decision, due to high upfront costs and the benefits lasting many seasons. It was unknown if amelioration had economic merit, therefore the fundamental question of deep-P placement is: "how much P, how often, and how profitable?"

What was done

Trial sites were setup across Queensland and NSW from summer 2011 onwards (Figure 1), with the first crops harvested in 2013. All sites were initially treated with background levels of nitrogen (N), potassium (K), sulfur (S) and zinc (Zn) in order to ensure that the sites were unconstrained by other nutrients (Table 2).

Each of the sites selected had a 10–30 cm Colwell-P of less than 10, and were chosen with the expectation that they would assist in determining where responses could be found. Only three of the sites had a 10–30 cm Colwell-P of greater than six.

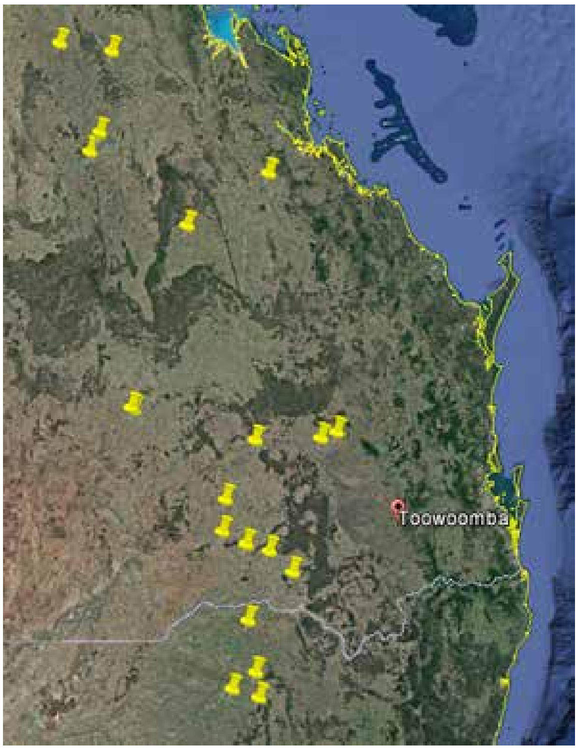


Figure 1. Trial site distribution

Rates of applied P at depth ranged from 0–80 kg/ha, with every site having a 0 and 20 kg P/ha rate, whilst the upper end (luxury) rates were either 40 and 80 kg P/ha, or 30 and 60 kg P/ha. The analysis in this report merges the results from 30 and 40 kg, and 60 and 80 kg P/ha rates, whilst keeping costs separate. The sites also had a farmer reference treatment, which was the farmer's normal fertiliser treatment of that paddock without any tillage as a baseline.

Although the applied type of fertiliser varied across trial sites, with choices driven by nutrients required and the price of different fertiliser mixes to achieve these requirements e.g. monoammonium phosphate (MAP) MAP versus diammonium phosphate (DAP), the economic analysis will use the urea for N, MAP for P and sulphate of potash (SOP) for K and S, with Zn applied as trace Zn (Table 2).

Table 2. Trial nutrient makeup and cost ($/t)

Nutrient	Applied As	Price ($/t)
Nitrogen (N)	Urea (46N)	$400
Phosphorus (P)	MAP (22P, 11N)	$800
Potassium (K)	SOP (41.5K, 18S)	$800
Sulfur (S)	SOP (41.5K, 18S)	$800
Zinc (Zn)	Trace Zn (93Zn)	$2000

Note i: N/ha background rate was total N applied to site pre-seeding, as MAP rate increased urea application was lowered by ~25%, Likewise SOP applied for 50 kg K/ha would also supply ~20 units of S

Costs for the application of deep-P when applied with current commercial farm equipment ranges from $15-$40/ha (as determined via case studies), however, the analysis in this paper will use a rate of $30/ha (Table 3).

Table 3. Estimated trial treatment costs by P rate ($/ha)

Treatment (P kg/ha)	Application ($/ha)	Urea ($/ha)	MAP ($/ha)	P Treatment Cost ($/ha)
0	$30	$69	$0.00	$99
20	$30	$61	$73	$164
30	$30	$57	$109	$196
40	$30	$52	$145	$227
60	$30	$43	$218	$291
80	$30	$35	$291	$356

Note ii: K and S were applied as backgrounding to ensure unconstrained soil for scientific results, grower implementation may be able to remove this cost depending on soil nutrient status

As noted above K and S were applied to eliminate other potential nutrient deficiencies and to ensure measured responses were to P. In practice if K and S levels were not deficient then this treatment would not be required, thus this paper will not be including the $96/ha in the analysis.

Average crop prices (Table 4) are used in order to avoid the large fluctuations in chickpea and mungbean prices that occurred during the trial period, to ensure that a percentage change in crop production in 2013 is equivalent to the same change in 2016. The use of average prices also gives a more realistic indication of the long term economics of deep-P.

Table 4. Average crop prices used in deep-P analysis

Crop	Price ($/t)
Barley	230
Chickpea	500
Mungbean	750
Sorghum	250
Wheat	250
Durum	300

Results

Positive yield responses greater than 5% to the 20 kg P/ha rate were witnessed in 30 of 43 observations, whilst 21 of 43 observations had responses of 10% or more. There does not appear to be a rate response between the rates of P used with rates from 20–80 kg P/ha providing a very similar range of responses across the 21 sites (Figure 2).

A number of sites appear to have had a positive response to the background K, N, S and Zn treatments, with the 0 kg P/ha treatment having an average yield response of 4%, and nine out of 46 responses being greater than 10%. The data (not shown) suggests that the sites with highest 0 kg P/ha responses were heavily influenced by K.

Three crop types dominate the dataset, with 41 out of 44observations being either chickpea (14), sorghum (14) or wheat (13). Chickpea yield responses were lower than both wheat and sorghum on average, however all crop types had a similar distribution (Figure 3). The solid sections of the box and whisker plots in Figure 2 represent the range of the middle 50% of results, whilst the tails contain the range of lowest and highest 25% of results.

There is a strong similarity in the responses between the different P rates (Figure 3), because of this further analysis in this paper will focus on the 20 kg P/ha rate, which is most likely to have provided net positive returns over a shorter time period given its lower upfront costs.

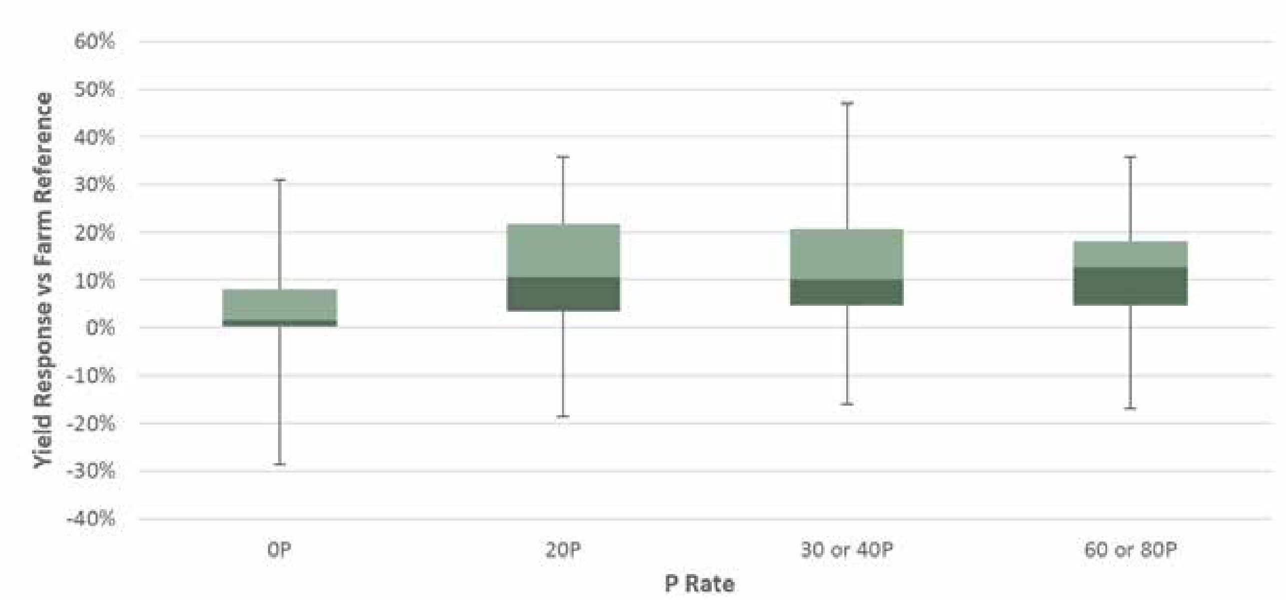


Figure 2. Distribution of yield responses across 46 observations per treatment vs farm reference

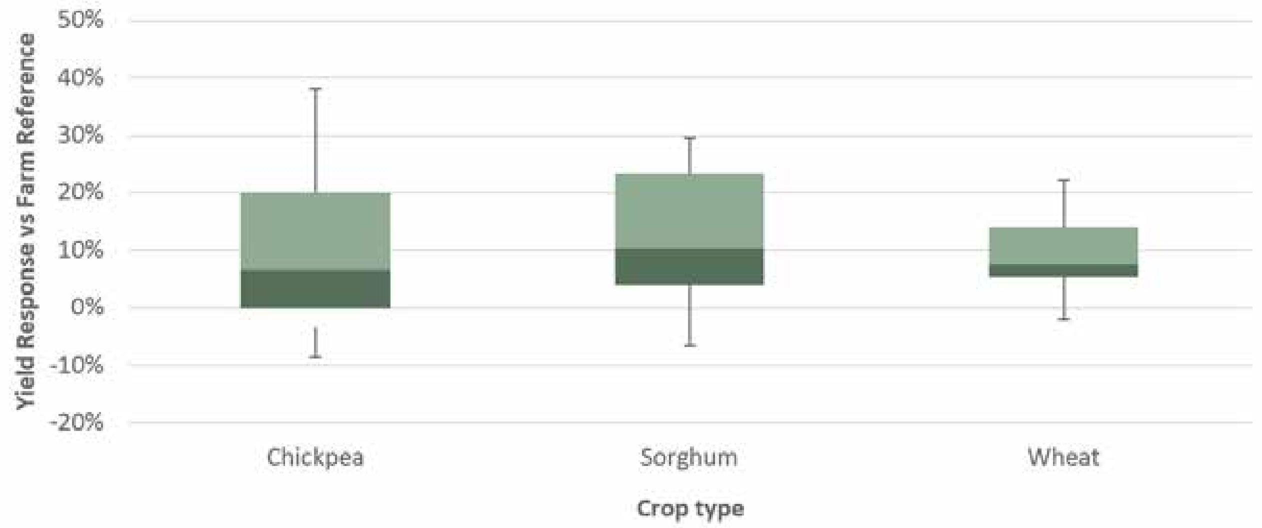


Figure 3. 20 kg P/ha yield distribution vs farm reference by crop type

Table 5. Cumulative net benefit generated over time by 20 kg P/ha treatment

	Year 1	Year 2	Year 3
Number of sites	21	15	7
Average cumulative net benefit	-$73	-$5	-$11
Max net benefit	$106	$222	$331
Number of sites with net benefit	5	9	3

Despite the background treatment of N in year one in all trials, some extremely low sorghum proteins were recorded in following years, suggesting that a number of sites may have been N constrained, which would mask any potential P response.

Only five of the 21 sites achieved a positive return in the first year (Table 5). This is typical of longer term decisions with large upfront costs and returns expected over a number of following years.

On average the 20 kg P/ha treatment generated an annual income of around $100/ha more than the farm reference treatment. Nine of the 15 sites generated profits in the second year, with an average profit increase of approximately $80/ha.

Unfortunately four of the seven sites (for which three or more years of data exist) were largely unresponsive and these sites failed to generate a profit after three years. There was no correlation between the sites that were unresponsive and their starting Colwell-P test results.

Implications for growers

The majority of sites achieved positive yield responses to deep-P application over the duration of the trials. In situations where K and S levels are already sufficient, the majority of sites would return a profit in the second year.

Responses to P have varied, with season type being an important factor. It is believed that in-season rainfall will allow plant access to P in the 0–10 cm layer, reducing the reliance on subsoil P, thus reducing the potential benefits. Seasons where there is minimal in-season rainfall are expected to obtain greater benefit from deep-P. Additional monitoring will be required to determine what the difference in duration of response is between the rates of P used and whether the higher rates can prove economical over time.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the Grains Research and Development Corporation and the Department of Agriculture and Fisheries across a number of projects, UQ00063 / DAQ00194 / CSA00036; the author would like to thank them for their continued support.

Reference

Bell Mike, Lester David, Zull Andrew, Cox Howard - (2014), *The economics of deep phosphorus use in marginal environments*. GRDC Update.

Sorghum with deep-P (front), without deep-P (rear)

Soils research

The main area of focus of the Department of Agriculture and Fisheries' Regional Agronomy team in the soils domain has been the management of soil organic matter. Soil organic matter is critical for healthy soils and sustainable agricultural production; however levels under cropping systems are continuing to decline. 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 the Department of Agriculture, Fisheries and Forestry (DAFF). These projects aim to help growers understand the functions of soil organic matter in grain production systems and 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 may have on soil organic carbon levels in current farming systems.

The demonstration sites investigated the potential of:

- Increasing soil organic matter under cropping comparing manure versus fertiliser
- Increasing soil organic matter by establishing productive pastures on long-term cropping country
- Increasing soil organic matter by applying nitrogen fertiliser to maximise production on established grass pastures

The site focused on applying nitrogen to maximise production on established grass pasture was finalised late 2016 and a summary of the results is included in this publication. The two remaining sites will be finalised in 2017 and summarised in the 2017 publication.

The main findings across these projects to date include:

- Long-term cropping across Queensland and New South Wales continues to deplete soil organic carbon levels.
- These changes in soil carbon appear to be driven by the lengthy fallow periods in current cropping systems.
- The resulting decline in available nutrient reserves (typically nitrogen) leads to increased use of fertiliser, extra costs and the reduced profitability of grain cropping over time.
- 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.

Planting pasture plots

Harvesting pasture plots

Increasing soil organic matter by applying nitrogen fertiliser to maximise biomass production on established grass pasture—Chinchilla

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Department of Agriculture and Fisheries

Research Question: *What is the soil organic matter (soil organic carbon) benefit of applying annual nitrogen applications to established grass pasture?*

Key findings

1. Soil organic carbon increased with the establishment of pasture.
2. Biomass was increased by approximately 200% with the addition of 100 kg N/ha/yr.
3. Soil carbon stocks trended upwards as nitrogen levels increased.

Background

Soil organic matter (SOM) levels have declined in cropping country. This decline is measured by changes in soil organic carbon (SOC), which makes up 60% of the SOM and is easier to measure. Decreases in soil organic carbon (SOC) of one to two percent are common throughout the brigalow cropping belt and in some areas can drop from over 3.5% to under 1.0%. This reduction in SOM can reduce the overall fertility and health of the soil. As a result research was undertaken to determine what farming practices have the ability to either slow, stop or reverse this decline in SOC/SOM.

A productive sown grass pasture phase is considered to be 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 adequate nutrient supplies to make a major contribution. Consequently, nitrogen (N) is required in most old cropping soils that have low levels of available N due to their declining soil carbon levels. The required N to maximise pasture production can be supplied to the system by the inclusion of a legume in the pasture mix or by the addition of N fertiliser. Fertilising pasture with N (as opposed to establishing a legume/grass mix) will be quicker and more effective at increasing SOC in the short-term, and may better fit a grain farming system. This trial was undertaken to determine the impact of the application of different annual N rates to a recently established grass pasture, its biomass production, SOC and ultimately SOM levels.

Treatments

The following treatments were applied to a two year old Rhodes grass pasture on a degraded sandy loam, with very low SOC, near Chinchilla with three replicates:

- Grass only (0 kg N/ha)
- Grass + 50 N kg/ha/year
- Grass + 100 N kg/ha/year

The fertiliser treatments were initially applied to the pasture in November 2012 and were repeated annually; September 2013, 2014 and 2015. Biomass cuts were taken from each plot as required, to determine pasture growth.

Results

Floods in 2012 damaged the grazier's fence and stock grazed the paddock prior to the first pasture biomass cut, which was subsequently estimated visually. However, a cut in May 2013 prior to frosts, still showed a carry-over yield response to the applied nitrogen of up to 20 kg biomass/kg N.

Excellent responses were seen in 2014 due to good rainfall events promoting strong pasture growth. Subsequent years have been less productive, but significant total biomass responses have still been measured between all treatments over the life of the trial.

The trial was damaged by pigs June/July 2016. As the pigs sought out the nitrogen treatments, the trial was deemed to have been too compromised to continue. Hence, it was subsequently sampled and finalised nine months early in August 2016. This was particularly unfortunate

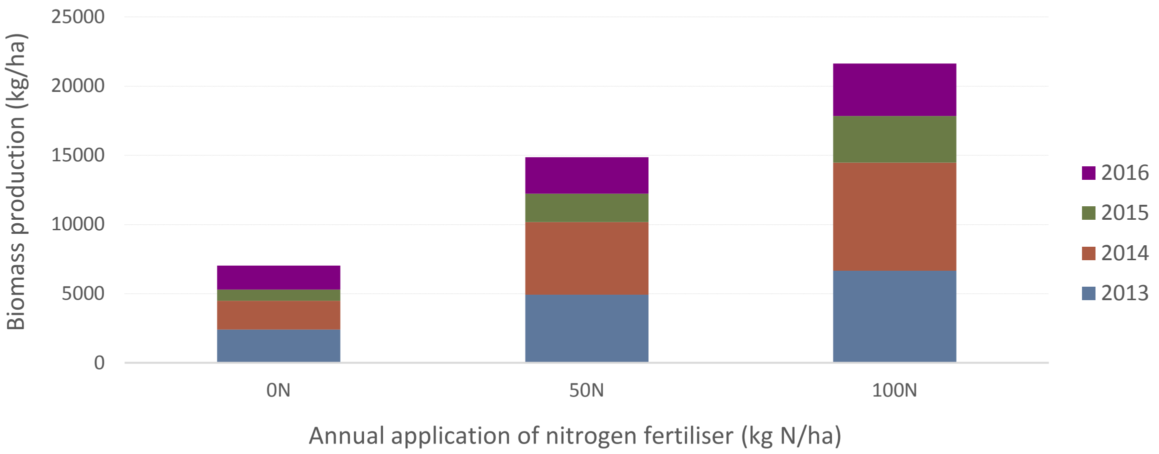

Figure 1. Impact of applying annual applications of nitrogen to grass only pasture
Note: 2013 was a visual assessment, 2015 season had a dry summer and the 2016 season shortened due to pig damage

as potential biomass production in the final year was not captured in the data.

In total, the annual application of 50 and 100 kg N/ha provided 7.8 (~100%) and 14.6 (~200%) tonnes of additional biomass respectively compared to the unfertilised pasture treatment (Figure 1). The average total organic carbon (TOC) levels at the beginning of the trial were extremely low (0.22% 0–10 cm and 0.12% 10–30 cm) reflecting the impact that long-term cropping has on SOC levels on lighter soil types. However, these lighter soils are expected to respond more rapidly to the additional biomass produced by a productive pasture.

Testing was conducted again at the completion of the trial in August 2016. The mean TOC (averaged across all treatments) in the 0–10 cm layer increased by 64% (p=0.000) with four years of pasture growth (Table 1). However, there was no significant change in 10-30 cm, most likely due to the short-term nature of the trial.

Table 1. TOC and carbon stock averaged across site

Trial average	Start (2013)	Finish (2016)	% change	P<0.001
TOC 0-10 cm (%)	0.22	0.36	64	yes
TOC 10-30 cm (%)	0.12	0.14	17	no
Carbon stock (t/ha)	6.90	8.89	29	yes

(BD (0-10) = 1.31; BD (10-30) = 1.53)

This change in TOC resulted in a 29% increase in mean carbon stocks (t/ha) to 30 cm. Although not significant, a trend was apparent with in carbon stocks at the end of the trial increasing as the amount of applied nitrogen fertiliser increased; the annual 100 kg N/ha treatment increased the mean SOC by 44% (Table 2).

Table 2. Change in carbon stock

Treatment	Start (2013)	Finish (2016)	% change
0 N	7.46	8.89	19
50 N	7.49	9.54	27
100 N	5.75	8.26	44

(BD (0-10) = 1.31; BD (10-30) = 1.53)

The economic benefit from this increased dry matter production on crop yields due to soil carbon increases is currently unknown. However, increased pasture production can be economically valuable in itself. It is calculated that the 50N treatment had the potential to generate an additional $784/ha of income over the four years, or $584/ha ($145/ha/yr) in additional profit, whilst the 100N treatment had the potential for $1460/ha in additional income or $1060/ha ($265/ha/yr) in profit compared to the unfertilised pasture[1]. If this pasture could be utilised by cattle, this is a win–win situation in terms of economics and improving SOM.

Implications for growers

Soil organic matter is an under-valued capital resource that needs to be managed. This trial indicates that well grown pasture phases will rebuild total organic carbon in the soil. However, there is strong evidence that TOC will accumulate faster with more productive pastures that produce more biomass. Good nutrient supplies are critical to maximise this biomass production. Consequently, a source of nitrogen (legumes, fertilisers, manures) will be needed

[1] Calculated using 12:1 Food Conversion Efficiency (FCE), a live weight beef price of $3/kg, and assuming 40% of additional dry matter is consumed it is possible to estimate the economic benefit of these treatments, with urea at $400/t.

in most old cropping soils that have low levels of available nitrogen due to their declining soil carbon levels.

This trial increased biomass by ~200% with the addition of 100 kg N/ha/yr to a recently established grass pasture on an older, rundown cropping soil. The results suggest strong economic returns and the potential for greater increases in carbon stock with the addition of N fertiliser.

Acknowledgements

The team would like to thank the farmer for hosting this trial. This project is funded by the Grains Research and Development Corporation and the Department of Agriculture and Fisheries.

Trial details

Location:	Chinchilla, Queensland
Crop:	Rhodes grass pasture
Soil type:	Light loam
Fertiliser:	as per treatment list


Soil core from trial


100 kg N/ha plot showing visible response

Farming systems research

Advances in agronomy and the performance of individual crops have helped grain growers to maintain their profitability. However, there is evidence that the current farming systems are underperforming; with only 30% of the crop sequences in Queensland and New South Wales (northern grains region) achieving 75% of their water limited yield potential.

Furthermore, growers in this region are facing challenges from declining soil fertility, increasing herbicide resistance, and increasing soil-borne pathogens in their farming systems. Changes will be needed to meet these new challenges and to maintain the productivity and profitability of our farming systems. 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 farming systems and crop sequences that can meet 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, and locally relevant systems being studied at six regional centres by Department of Agriculture and Fisheries (DAF) in Queensland and the Department of Primary Industries (DPI) in New South Wales (Table 1). Several of these systems are represented at every site to allow major insights across the northern grains region, while the site specific systems will provide insights for local conditions.

The following reports provide details of the systems being studied at each experiment in Queensland, the way they are implemented locally and their initial results.

Table 1. Summary of the regional farming systems being studied at each location in the Northern Farming systems initiative

	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		Grass (+/-N)				
Higher Soil Fertility (higher nutrient supply plus organic matter) as in the high nutrient system but with compost/manure added	*	*				
Integrated Weed Management (incl. tillage) included at Emerald where crops, sowing rates, row spacings and 'strategic tillage' are included to manage weeds and herbicide resistance	*					

Northern Farming Systems site—Emerald

Darren Aisthorpe and Ellie McCosker
Department of Agriculture and Fisheries

Research Questions: *Can systems performance be improved by modifying farming systems in the northern grains region? In Emerald: (i) What are the trends that are expected in our farming systems? (ii) How will these changes impact on the performance and status of our farming systems?*

Key findings

1. Deep planted chickpeas were the most profitable of the rotations for 2016.
2. The higher crop intensity system is to date performing the worst, in terms of average gross margin over two years.
3. When late planting wheat, even two weeks can make a significant difference in yield.

Background

The Central Queensland (CQ) growers traditionally used a summer focused cropping system because of the high proportion of annual rainfall during the December–March period. However, most crop-focused businesses now operate a zero or minimum tillage system with a strong reliance on stored fallow moisture. The moisture conservation process has been refined over the past 20 years and the inclusion of better adapted winter cropping options has seen the proportion of winter: summer crops narrow and now be close to a 50:50 distribution.

What was done?

In late 2014 and early 2015, six locally relevant systems were developed to investigate at Emerald. The site was established in the winter of 2015 at the Emerald Campus of the Queensland Agricultural Training College. The paddock was previously irrigated cotton in 2013/14, sorghum in 2012/13 and chickpea in winter 2012. The project established six local farming systems that were consistent with those being studied by the Northern Farming Systems initiative (Table 1, previous page):

1. **Baseline:** A moderately conservative zero tillage system that is commonly used. It has approximately 1 crop/year, with fertiliser applied to match 50 percentile yield expectation for the plant available water (PAW) at planting. Crops include: wheat, chickpea, sorghum (summer only).
2. **Higher Legume:** The frequency of pulses is increased 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 + new legume crops.
3. **Higher Crop Intensity:** This system is focused on increasing the cropping 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 more sustainable from both from an agronomic and economic point of view? Crops include wheat, chickpea, sorghum, mungbean, forage crops/legumes.
4. **Higher Nutrient Supply:** This system applies fertilisers to supply adequate nutrition to support 90% of the potential yield based on soil moisture (PAW) at planting. So, what is the economic implication of increased nitrogen and phosphorus rates that target higher yields and protein levels in an environment of 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 knockdown herbicides in CQ farming systems. Practices include tillage with full disturbance planting; contact and residual herbicides; and other cultural practices such as high plant population, narrow rows, crop choice and other emerging technologies. Crops include wheat, chickpea, sorghum and mungbean.

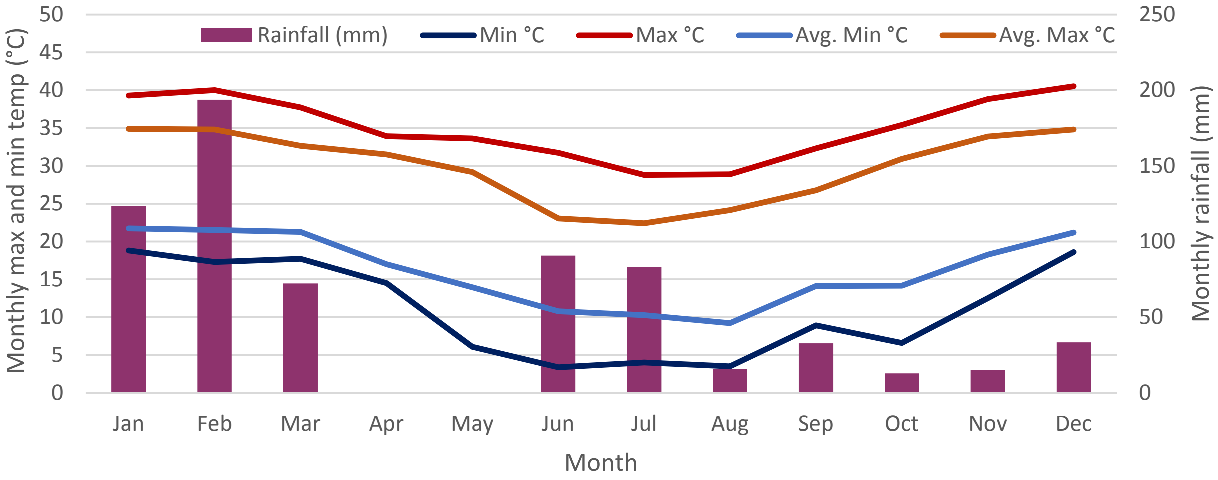

Figure 1. Monthly rainfall and temperature observations in 2016 at the Emerald site

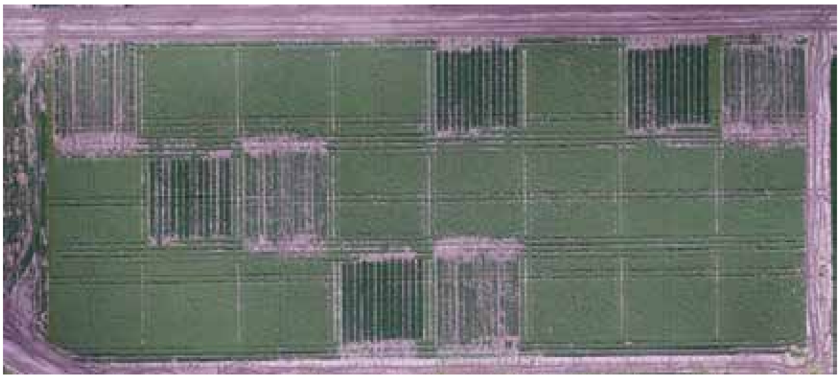

Figure 2. The Farming systems site at Emerald—July 2016

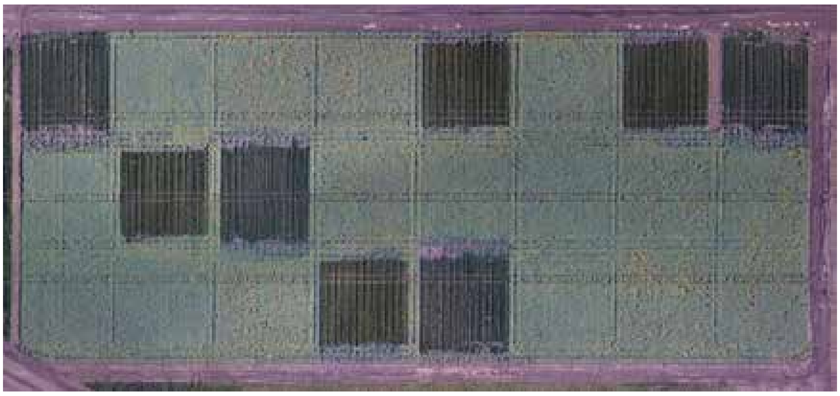

Figure 3. The Farming systems site at Emerald—August 2016

Figure 4. The Farming systems site at Emerald—October 2016

The 2016 summer crop

The summer of 2015-16 was dry until late January when significant summer rain arrived between the last week of January and mid-March. (Figure 1). There was a brief opportunity between rainfall events and the close of the summer planting window to plant the *Higher Crop Intensity* treatment to mungbeans on 12 February 2016.

PAW at planting was adequate, and with good establishment across all four replicates, the crop progressed very quickly. Physiological maturity (80-90% black pod) was achieved by 13 April, at approximately 56 days after planting. Conditions turned very dry and warm after mid-March.

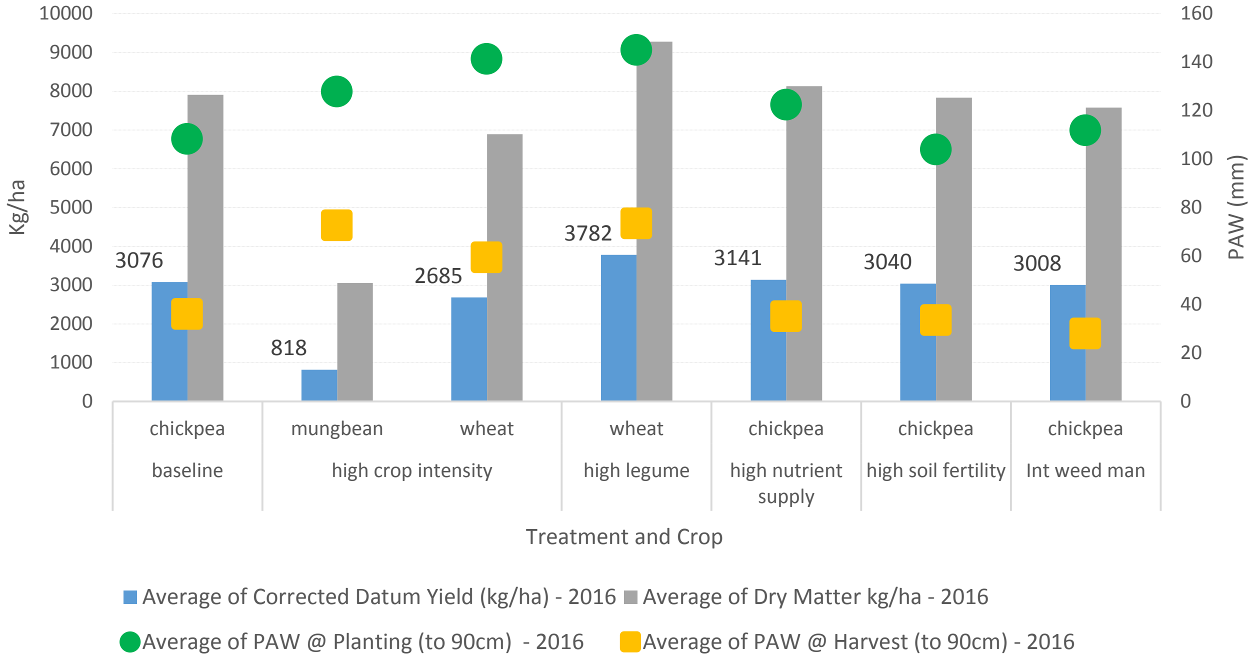

Figure 5. Crop production summary for the 2016 season; grain yield, dry matter production and plant available water at planting and harvest

Winter crops

Despite little rain and a growing layer of dry topsoil, there was still sufficient PAW across the treatments in mid-April/early May; ranging from 103-122 mm down to 90 cm. This met the planting triggers for all treatments. Four treatments; *Baseline*, *Higher Crop Intensity*, *Higher Nutrient Supply* and *Integrated Weed Management* were deep planted with Kyabra⁽ᴰ⁾ chickpea. They were planted to a depth of 15-20 cm with a target population of 20 plants/m^2. Establishment was less than ideal (between 8-10 plants/m^2). However, with the excellent in-crop rain, plants compensated well and full canopy coverage was achieved late July with first flowers observed mid-July. Nodulation on the plants was satisfactory when assessed in August.

The *Higher Legume* treatment was similarly deep planted to Condo⁽ᴰ⁾ wheat with a target population of 50 plants/m^2. Establishment was too low and the crop was sprayed out. The treatment was replanted on 25 cm rows to compensate for a late planting on 16 June. Rain on 19-20 June allowed the *Higher Crop Intensity* treatment to be planted on 1 July, again with 25 cm rows. The progress of the crops is shown in Figures 2, 3 and 4.

Results

Both yield and biomass production were good (Figure 5) and average yields (the blue bars) were significantly higher than those in 2015. The average yields for the chickpea were all over 3 t/ha, while the wheat yield in the *Higher Legume* treatment was up to 3.8 t/ha despite the late planting. The *Higher Crop Intensity* treatment, which had just come out of mungbean two months earlier, still averaged over 2.5 t/ha.

The *Higher Intensity* mungbean was the only crop where yield did not match the expectations based on water availability at planting or the biomass production. Conditions turned hot and dry after the rain in mid-March, and the failure to seek stored soil moisture appeared to have a major effect on final yield. PAW at planting (the green dots) and the finishing PAW (the yellow dots) based on wheat lower limits for each crop shows the low water use efficiency of the mungbean compared to the chickpea and wheat. The gap between the green and yellow dots is much narrower for the mungbean.

The considerable biomass production with low populations resulted in some lodging in most chickpea treatments. All chickpea and wheat treatments ripened very quickly under hot conditions and were harvested on 12-13 October.

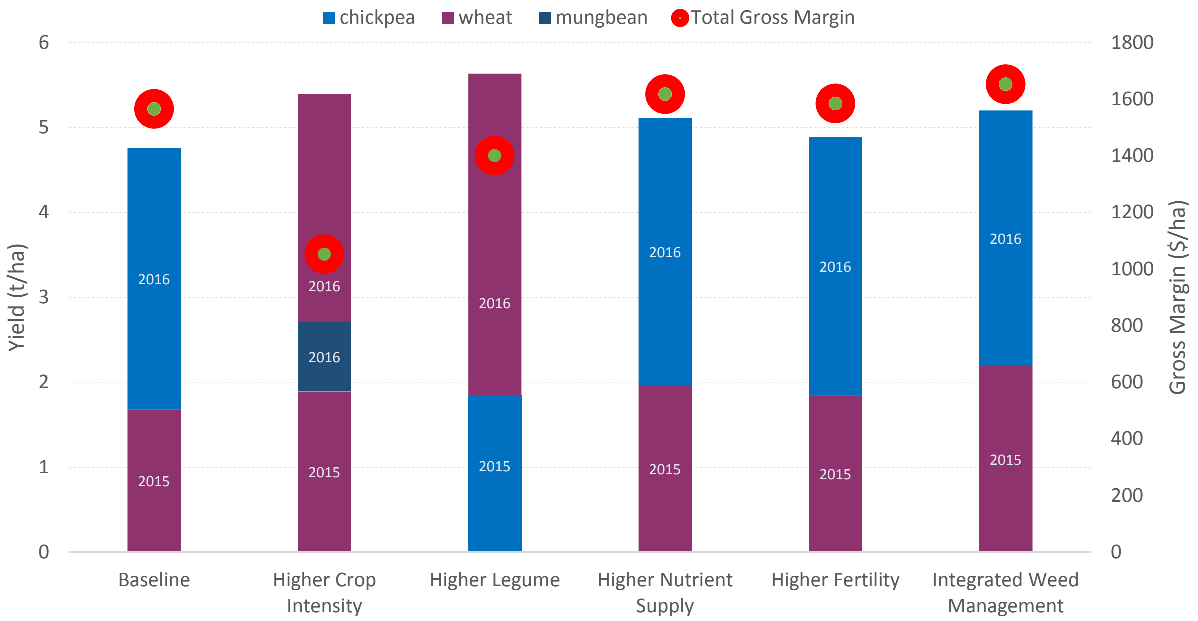

Figure 6. Cumulative grain yields and total gross margins (including fallow costs) of crops and systems at the Emerald site up to the end of the 2016 winter system

Economics

There is minimal difference in gross margins at this point in time between all treatments (Figure 6). The main difference is for the *Higher Crop Intensity* treatment, which has had the production cost of three crops instead of two for no real production advantage at this point in time. However, it is very early to be drawing any serious conclusions at this time, especially given the low yield of the mungbeans and the exceptional yield of the chickpea and wheat for winter 2016.

Implications for growers

This is a long-term trial, and while there are no strong long-term trends between treatments, it has been interesting to note some of the agronomic and economic consequences of triggers such as planting date and crop rotation options, and to see how they can affect the production ability and economics of the site. Consequently, we expect to start seeing the treatments separate over the coming seasons.

Acknowledgements

We would like to thank the local growers and consultants that have supported and contributed to the project.

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

Trial details

Location:	Queensland Agricultural Training College – Emerald
Soil type:	A cracking, self-mulching, Grey Vertosol, over 1.5 m deep with a plant available water holding capacity of 230–240 mm
Crops and fertilisers (2016):	No nitrogen was applied as there was already sufficient available in the profile for winter cereals (174-194 kg N/ha). All systems had 26-27 kg/ha of Granuloc Z® applied

Crops and planting details:

- **Baseline:** Kyabra⦷ chickpea planted on 6 May at 80 kg/ha on 50cm rows
- **Higher Crop Intensity:** Jade-AU⦷ mungbean planted on 12 February at 27 kg/ha. Condo wheat planted 1 July on 25 cm spacing
- **Higher Legume:** Condo⦷ wheat planted on 1 July on 25 cm spacing
- **Higher Nutrient Supply:** Kyabra⦷ chickpea planted on 6 May at 80 kg/ha on 50 cm rows
- **Higher Soil Fertility:** Kyabra⦷ chickpea planted on 6 May at 80 kg/ha on 50 cm rows
- **Integrated Weed Management:** Kyabra⦷ chickpea planted on 6 May at 80 kg/ha on 50 cm rows

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? In Goondiwindi: (i) What are the trends that are expected in our farming systems? (ii) How will these changes impact on the performance and status of our farming systems?*

Key findings

1. 2016 winter crops were high yielding.
2. Pulse crops matured prematurely in a wet spring, leaving moisture available for a double crop opportunity.
3. The addition of nitrogen fertiliser has increased the dry matter production of the Bambatsi grass pasture.

Background

The Goondiwindi area is largely based on a winter cropping system with summer crops grown as a disease break. Most farms operate on a zero or minimum tillage system, with strong reliance on stored fallow moisture. Summer crops are seen as an important part of the system, however are often grown on a fuller water profile than winter crops as an insurance against hot growing seasons with variable rainfall.

The Billa Billa site is located 50 km north of Goondiwindi on the Leichhardt Highway. The soil is a Grey Vertosol. The original belah and brigalow trees were cleared and paddock used as a long-term pasture before being developed for crops 15 years ago.

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 ~1 crop per year grown using 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. These crops are fertilised to achieve average seasonal yield potential for the PAW prior to planting.
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 (Repeated back into wheat/barley) with the same minimum PAW triggers for planting and nutrient management as the *Baseline* system.
3. **Higher Crop Diversity** allows a greater suite of crops to be grown to better manage disease, root lesion nematodes and herbicide resistance. Moderate PAW levels for planting each crop (ranging from 90 mm to 120 mm) have been identified to manage individual crop risk and to target one crop per year. These crops are fertilised to achieve the average seasonal yield potential. The unique rules for this system focus on managing root lesion nematodes, with 50% of the selected crops to be resistant to *Pratylenchus thornei*, and 25% of crops resistant to *Pratlenchus neglectus*. To manage herbicide resistance, two crops of the same herbicide mode-of-action cannot 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 crop as a pulse (legume), 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 planting triggers of 90 mm to 120 mm PAW. Crops will be fertilised to achieve average yield potential, with nitrogen only applied to the cereal crops.
5. **Higher Crop Intensity** aims to minimise the fallow periods within the system and potentially grow 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 mungbean added as a short double-crop 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 the *Higher Nutrient Supply* system. However, it had an upfront addition of organic carbon (compost) at the start of the experiment to raise the inherent fertility of the site and to 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. The pasture will removed after 3-5 years and returned to the Baseline cropping system to quantify the benefits gained by the pasture phase. The pasture will be managed with 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* but with 100 kg N/ha (217 kg/ha Urea) applied each year over the growing season. This will boost dry matter production that is nearly always constrained by nitrogen deficiency in grass-based pastures.

Results

The summer of 2015-16 was dry with storm rain contributing to the majority of the profile moisture accumulation. The *Higher Crop Intensity* plots accumulated sufficient water to be planted to mungbean on 15 January (Table 1). The next rain this crop saw was after spraying out; resulting in a low yield of 0.35 t/ha.

There was little rain in April, so faba bean were deep-planted (to 15 cm) on 28 April, with 12 mm five days later helping to establish a good population. With continuing dry conditions into May, the field pea treatments were deep-planted (to 10 cm) on 26 May. A 10 mm fall of rain the next day allowed the barley to be shallow planted on 31 May.

With only 75 mm of rain from harvest to the end of July, the *Higher Crop Intensity* system was left fallow. The *Lower Crop Intensity* system was also long-fallowed in preparation for a sorghum crop. Above average rainfall in September meant these two fallowed systems had full profiles to 150 cm to plant sorghum. However, the extended cool conditions kept soil temperatures low and the sorghum was planted into 14°C soil on 15 October. Sorghum yields will be reported in next year's update.

The wet conditions in September led to premature senescence of the faba bean. The field pea lodged at this point and subsequently matured quickly due to broken stems. These crops were harvested in mid-October for yields of 3.55 t/ha and 3.8 t/ha respectively. There was in excess of 150 mm PAW remaining in the soil profile of both of these systems, but it was decided to spray the weeds that had established 'in-crop' before planting a summer crop in December.

The barley also lodged in September, but with the continuing wet conditions put out late tillers that delayed harvest by four weeks to 16 November. The barley yielded 6.1 t/ha with an estimated yield of 1 t/ha contributed by the late crop. This extended growing period meant that the profile was dry after harvest; unlike the systems with pulse crops.

A comparison of cumulated grain yields and net value ($ per hectare) at this early stage of the experiment indicates that income aligned closely to the total tonnage of grain produced (Figure 1). It should be noted that these values are calculated from the beginning of the trial in March 2015 to the end of winter crop harvest in 2016.

Bambatsi grass pastures were planted on 2 November 2015 into 150 mm of PAW after a wheat cover crop (sprayed out in August 2015). Grazing was simulated by cutting with a forage harvester at 50% flowering. The pasture plots were cut twice in 2016, leaving approximately one third of the plant height each time. After growing 5 t/ha of dry matter (DM) the pasture was first cut on 29 February. On this occasion the grass was mulched back onto the ground, and 50 kg N/ha (as urea) was broadcast onto the *Grass Ley Pasture + Nitrogen Fertiliser* system before the next rainfall event. The pasture was slow to start growing in the spring due to cool conditions of September and October 2016. The spring flush was cut on 30 November with 7.9 t DM/ha in the fertilised and 6.4 t DM/ha in the unfertilised pastures. This time approximately 2.0 t DM/ha removed from

Table 1. Crops grown at the Billa Billa site—yields for spring/summer 2015-16 and winter 2016

	Winter 2015	Spring 2015	Summer 2016	Winter 2016	Spring 2016	Summer 2017
1. Baseline	Wheat EGA Gregoryᶲ			Barley Compassᶲ		
2. Lower Crop Intensity	Wheat EGA Gregoryᶲ				Sorghum MR-Bazely	
3. Higher Crop Diversity	Wheat EGA Gregoryᶲ			Field pea PBA Whartonᶲ		Sorghum MR-Bazely
4. Higher Legume	Wheat EGA Gregoryᶲ			Faba bean PBA Nasmaᶲ		Mungbean PBA Jadeᶲ
5. Higher Crop Intensity	Wheat EGA Gregoryᶲ		Mungbean PBA Crystalᶲ		Sorghum MR-Bazely	
6. Higher Nutrient Supply	Wheat EGA Gregoryᶲ			Barley Compassᶲ		
7. Higher Fertility	Wheat EGA Gregoryᶲ					
8. Grass Ley Pasture	Wheat EGA Gregoryᶲ	Bambastsi	Bambastsi	Bambastsi	Bambastsi	Bambastsi
9. Grass Ley Pasture (+Nitrogen)	Wheat EGA Gregoryᶲ	Bambastsi	Bambastsi 50 kg N/ha	Bambastsi	Bambastsi 50 kg N/ha	Bambastsi 50 kg N/ha

both systems to avoid a mulching effect of the biomass on the pasture. With only 50 kg N/ha difference between the systems at this point there was only a small difference in biomass production and protein levels in the feed were the same. Another 50 kg N/ha was applied in front of the next rainfall event.

Implications for growers

The most profitable systems to date have been a direct result of the exceptionally high yields achieved in the cereal crops grown in 2015 and 2016. This site had 300 kg N/ha available at the time of planting wheat in 2015 and has needed no nitrogen fertiliser to grow the 11 t/ha of cereals to date. Post-harvest soil tests indicate these cereal systems had 50 kg N/ha remaining (November 2016), whereas the two systems that

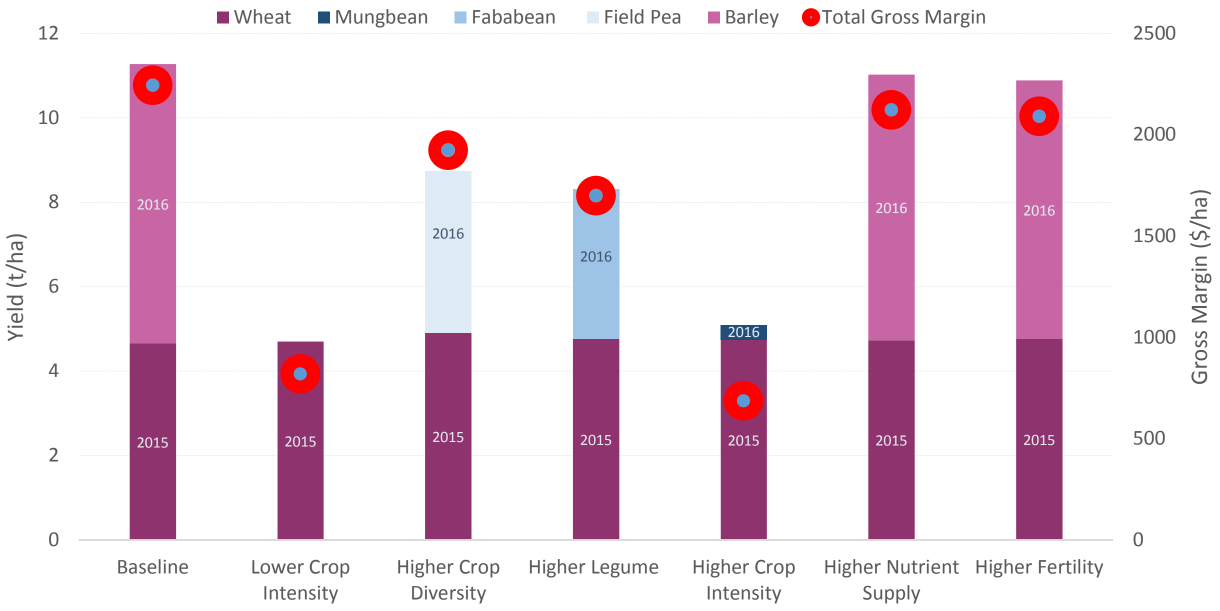

Figure 1. Cumulative grain yields and total gross margins (including fallow costs) of these crops and systems at the Billa Billa site up to the end of the 2016 winter season

had a pulse crop in 2016 had 100 kg N/ha left. Combined with the extra PAW remaining after the pulse crops, there is opportunity to reduce the gap in system profitability with the next crop grown.

The comparison between the *Lower Crop Intensity* and *Higher Crop Intensity* systems is also worth noting. The mungbean grown in the *Higher Crop Intensity* system was low yielding but still covered costs, while the *Lower Crop Intensity* system had the cost of fallow sprays with no income. Both these systems have since been planted to sorghum on the same day with similar PAW.

A wet spring (September 2016)

Simulated grazing of pastures

Acknowledgements

The team would like to thank the trial co-operator, local growers and consultants for their ongoing support and contribution to the project. Thanks also to the Grains Research and Development Corporation and the Department of Agriculture and Fisheries for funding the project.

Trial details

Location:	Billa Billa
Crops:	Bambatsi panic (grass), mungbean, faba bean, field pea, barley
Soil type:	Belah, Grey Vertosol
2016 rainfall:	478 mm

Billa Billa trial area 5 August 2016 (faba beans in foreground)

Northern Farming Systems site—Mungindi

Jo Weier
Department of Agriculture and Fisheries

Research Questions: *Can systems performance be improved by modifying farming systems in the northern grains region? In Mungindi: (i) What are the trends that are expected in our farming systems? (ii) How will these changes impact on the performance and status of our farming systems?*

Key findings

1. A combination of fallow periods and increasing crop diversity is having an impact on reducing nematode numbers at the site.
2. Late planting of chickpeas combined with waterlogging has had a negative impact on yield.

Background

The Mungindi farming area is based on winter cropping; mainly cereals (wheat and barley) and chickpeas, with limited opportunity summer cropping. The rainfall is variable and the winter crops rely heavily on stored moisture, typically from the highest rainfall months of late summer.

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 site is located 22 km north west of Mungindi towards Thallon on a Grey Vertosol soil with a plant available water capacity (PAWC) of 180 mm. The site has been cropped for 25 years and is representative of a large proportion of cropping in the region. The site has no major weed pressure but has high nematode populations (*Pratylenchus thornei*) that range from 6,000-26,000/kg of soil. The area has been fenced to keep wildlife away from the plots.

Treatments

Six systems were identified as priorities through consultation with farmers and advisers in the Mungindi Cropping Group.

1. **Baseline.** Designed to represent a standard cropping system for the Mungindi region. This baseline system is winter dominant with an average of one crop per year. The three main crops are wheat, barley and chickpeas typically on a fairly set rotation of wheat/wheat/chickpea.
2. **Lower Crop Intensity (Grain Only).** This system is designed to plant at a lower frequency; when the profile is at least 75% 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.
3. **Lower Crop Intensity.** Similar to the ‘grain only' option above but may also include dryland cotton as a high value crop, specifically to assess the impacts on water recharge and future grain production when cotton is grown.
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 mung beans.
5. **Higher Legume.** Focused on soil fertility and reducing the amount of nitrogen provided through fertilisers. The system requires that one in every two crops is a legume. 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 management 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* system so that the two treatments can be compared.

Results

The paddock grew wheat in 2014 and most of the systems were again planted to wheat in 2015 (Table 1). However, the *Higher Crop Diversity* system was prepared for a summer crop to avoid three winter cereals in a row, while the *Lower Crop Intensity* systems did not reach the necessary moisture level for planting.

The *Higher Crop Diversity* system was planted to sunflowers on 1 September 2015 after its fallowing through the 2014 winter. Sunflowers were chosen as the site had a high number of *Pratylenchus thorneii*. The crop was challenged by the dry conditions that followed its establishment. In-crop rainfall totalled 140 mm and the crop yielded 0.65 t/ha with an average oil content of 43.65 %. This yield was slightly higher than the average yield predicted by the APSIM model for the area.

Single-skip sorghum was planted in the *Lower Crop Intensity* system on 15 January 2016. These lower intensity plots had been fallowed since the winter crop in 2014 and received storm rain to plant in early January. The crop received 98 mm of rainfall and yielded 1.8 t/ha which reflected the lack of in-crop rain received.

The *Baseline*, *Higher Nutrient Supply* and *Higher Legume Systems* were all planted to chickpeas on 4 July when the moisture trigger of 80 mm was reached. PBA Seamer⦶ was the chickpea variety chosen as it is resistant to *Aschochyta* and moderately resistant to *Phytophera* root rot. This planting date was two weeks later than most planting in the district. Chickpeas were harvested on 12 December with an average yield of 1.4 tonnes/ha for all three systems.

Above average rainfall for the winter months led to considerable waterlogging of the site, which combined with a later planting date resulted in reduced chickpea yields. The majority of this rain fell in September when plants were 6-8 weeks old and were not able to cope with the prolonged wet. There was no significant difference between the performances of chickpeas in the three systems.

Although the site has only seen three cropping opportunities harvested the best performing systems have been the wheat/chickpea combinations.

The 2015 wheat yield in the *Higher Nutrient Supply* system was approximately 500 kg/ha lower than the *Baseline*, *Lower Crop Intensity (Grain Only)* and *High Legume Systems*. This lower yield combined with increased fertiliser costs to result in a penalty of around $200/ha in 2015 and an overall gross margin to date being lower with the addition of more nutrients (Figure 1). It should be noted that long term average prices are used to calculate gross margins.

The *Higher Crop Diversity* system was planted to sorghum on 12 October 2016 and the *Lower Crop Intensity (Grain Only)* system was planted to cotton on 13 October 2016. The 2016 summer crops had not been harvested at the time of writing.

Table 1. Crops grown at the Mungindi Farming Systems site

	Winter 2015	Spring 2015/ Summer 2016	Winter 2016	Spring 2016/ Summer 2017	Winter 2017
1. Baseline	Wheat EGA Gregory⦶		Chickpea PBA Seamer⦶		Wheat/Barley
2. Lower Crop Intensity	Wheat EGA Gregory⦶			Cotton Sicot 748 B3F	
3. Lower Crop Intensity (Grain Only)		Sorghum MR-Bazely			Wheat/Barley
4. Higher Crop Diversity		Sunflower Ausigold 62		Sorghum MR-Bazely	Wheat/Barley
5. Higher Legume	Wheat EGA Gregory⦶		Chickpea PBA Seamer⦶		Wheat/Barley
6. Higher Nutrient Supply	Wheat EGA Gregory⦶		Chickpea PBA Seamer⦶		Wheat/Barley

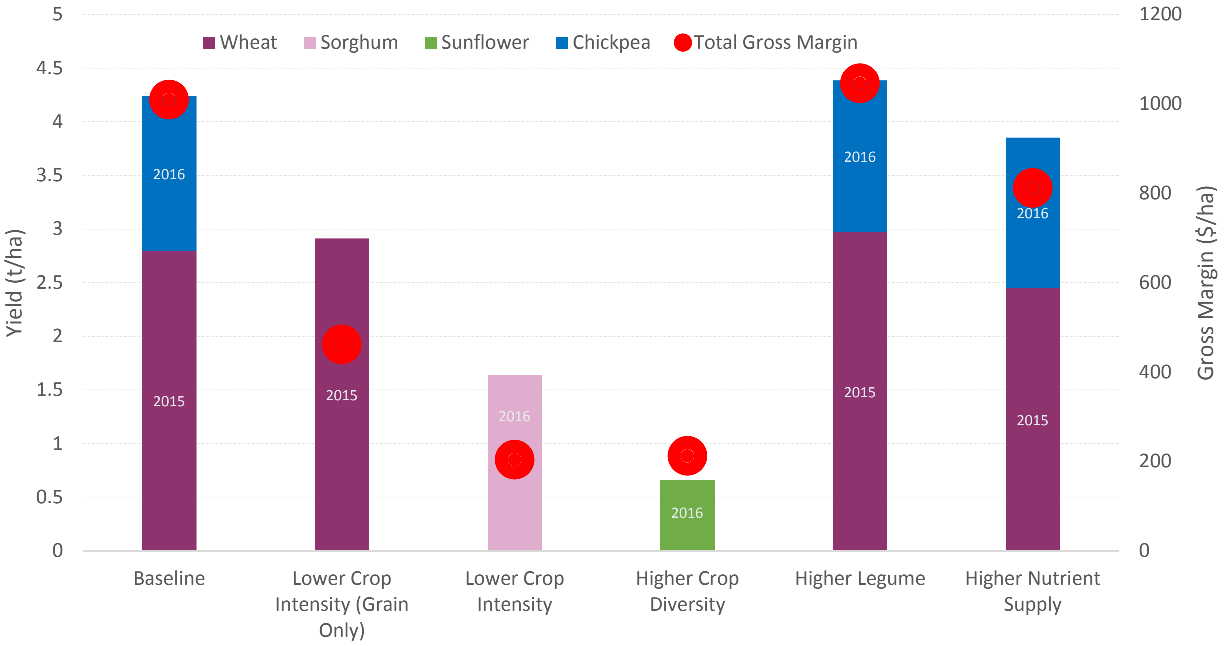

Figure 1. Cumulative grain yields and total gross margins (including fallow costs) of the crops and systems at the Mungindi site up to the end of the 2016 winter season

Implications for growers

At this early stage of the farming systems trial the most profitable crop sequence has been the wheat/chickpea rotation that can be seen in the *Baseline*, *Higher Legume* and *High Nutrient Supply* systems.

Acknowledgements

The team would like to thank the trial co-operator, local growers and consultants for their ongoing support and contribution to the project. Thanks also to the Grains Research and Development Corporation and the Department of Agriculture and Fisheries for funding the project.

Trial details

Location:	Bullawarrie, Mungindi
Previous Crop:	Wheat 2015
Crops 2016:	Chickpeas, sorghum, sunflowers, cotton
Soil type:	Grey Vertosol
2016 rainfall:	261 mm

Sorghum in the low intensity plots, March 2016

Chickpeas following a severe waterlogging event, October 2016

Northern Farming Systems site—Pampas

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Research Questions: *Can systems performance be improved by modifying farming systems in the northern grains region? At Pampas: (i) What are the trends that are expected in our farming systems? (ii) How will these changes impact on the performance and status of our farming systems?*

Key findings

1. *Pratylenchus thornei* numbers increased dramatically with double crops of susceptible varieties while resistant varieties (e.g. durum wheat and canola) or fallows have seen populations slowly decline.
2. Mungbean yields were higher following canola than other winter crops such as wheat or faba beans.
3. A double-crop of mungbeans had a yield penalty for the subsequent sorghum crop compared to maintaining a fallow.

Background

To complement the range of regional farming systems experiments, the core research site is comparing a wider range of cropping systems found across the region and how modifications to these impact on system performance. This experiment involves 38 different farming systems which are testing the impact of key system drivers on systems productivity, profitability and sustainability. In contrast to the regional sites, this experiment aims to explore the interactions of system modifications and hence provide a central hub to enable cross site analysis across the range of regional locations.

The site is located 10 km north of Pampas on the Condamine flood plain of the Eastern Darling Downs. The site has a Grey Vertosol soil with a plant available water capacity (PAWC) of 250 mm. The site has been cropped for >50 years and has been under no-till management for >20 years. The site has no major soil constraints and has high levels of soil phosphorus (P) and organic carbon compared to many regions. However, the site had high populations of root lesion nematode populations (*Pratylenchus thornei*) at the start of the experiment (>6000/kg soil) and has a range of weeds common to no-till systems (fleabane, sowthistle, feathertop Rhodes).

What was done

The 38 systems being compared at the core experimental site aim to represent the diversity of different cropping systems being utilised across the northern grains region, which can range from summer or winter-crop dominated systems, to opportunity systems involving summer or winter crops. To capture this variation, there are 30 crop-only systems and eight systems which involve rotations of pastures in the cropping sequence (no grain crops have yet been sown). The crop-only systems include:

- Eight that are summer crop focused (i.e. >60% summer crops)
- Eight that are winter crop focused
- Eight that are opportunity mixed summer-winter crop systems
- Six that involve more aggressive mixed summer-winter crop systems where crops are sown on a lower soil water threshold.

Within these systems a set of six modifications are being compared individually as well as the interactions when they are implemented in combination. These treatments were identified as priorities across the northern grains region through wide consultation with farmers and advisers in many regions and are consistent with those being implemented at the various regional sites.

The key system modifications that are being compared are:

1. **Baseline.** Designed to represent a standard cropping system.
2. **Higher Crop Intensity.** Designed to increase the time that crops are growing or the frequency of crops grown in the cropping system in order to maximise the proportion of rainfall that is transpired by crops. This involves planting on a lower soil water threshold (e.g. 1/3 full profile or 80 mm PAW) than other systems which apply a more conservative approach (e.g. 2/3 full profile or 160 mm PAW).
3. **Higher Crop Diversity.** Uses a wider range of crop options to help manage and reduce nematode populations, disease and herbicide resistance. This system requires two sequential crops resistance to root lesion nematodes in four years, and the same crop can't be sown within three years. Hence, this system includes many more 'break' or alternative crops in the cropping sequence.
4. **Higher Legume.** Aims to increase the inputs of biological nitrogen (N) from legumes in the system to reduce fertiliser N inputs. Every second crop is to be a legume separated by a non-legume crop.
5. **Higher Nutrient Supply.** Aims to boost background soil fertility and provide crops with adequate nutrients to maximise yield potential for that year. Fertiliser budgets are targeting crop yields in a 'decile 9' season accounting for any additional N present in the soil from previous seasons.
6. **Lower Crop Intensity.** Compares an approach where a longer fallow is maintained in order to fill the soil profile fully before sowing a high value-high returning crop. This system is not used in combination with the other treatments above.

The experiment began in March 2015 and has been running for two years. A range of winter crops were sown in the first winter May 2015 and all systems have had two or three crops sown.

Results

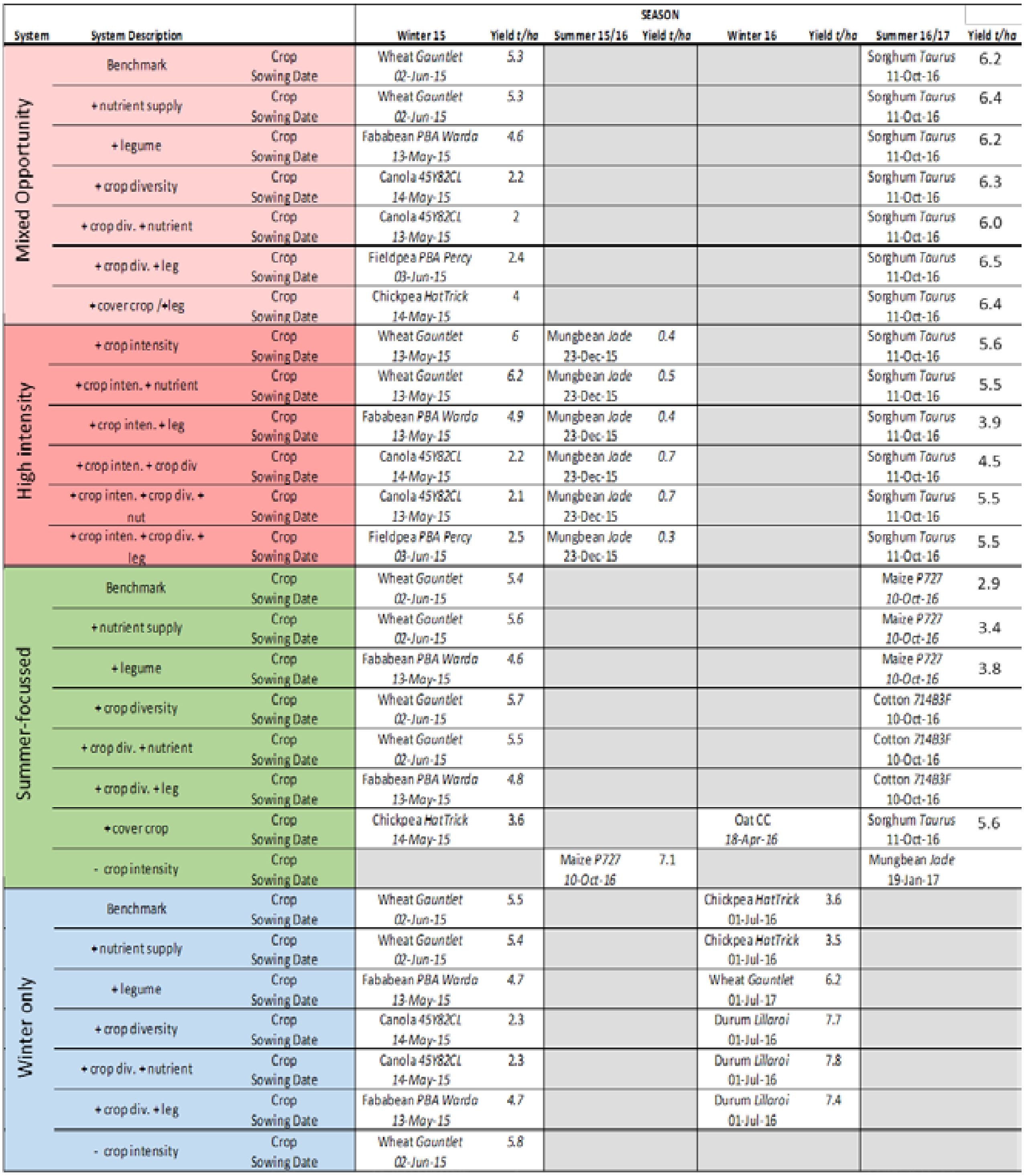
System crop sequences and yields

As the experiment has progressed, the crop sequences that have been implemented have increasingly distinguished between the systems. Table 1 shows the crops and the grain yields achieved from each system until March 2017. It can be seen here that the high intensity systems have had an additional mungbean double crop during the summer of 15/16, while the other systems remained fallow due to insufficient accumulated plant available water. In winter 2016, crops were only sown in the winter-only systems as the mixed opportunity systems did not meet the soil water threshold to plant before the end of July.

Some clear differences can be observed in crop grain yields achieved under the different crop sequences and systems. The first was the 0.5-0.7 t/ha higher yield achieved by LongReach Gauntlet$^{\Phi}$ wheat sown earlier (13 May) compared to the standard sowing date in the first winter of 2015. The second is the effect of the proceeding crop on the yield of the mungbean double crop in summer 15/16. Table 2 shows the break crop effect that canola has had on mungbean compared to wheat or faba bean. The grain yield benefit of 0.3-0.4 t/ha in this dry season was mostly likely attributable to the lower population of root lesion nematodes (*P. thornei*) which may have also reduced the impact of fusarium wilt. The other observation here was the difficulty in controlling volunteer field peas in the mungbean double crop, which contributed to the lowering yield.

Aerial view of Pampas trial site, May 2017

Table 1. Overview of crops grown in each farming system over the first two years including details of the variety, sowing date and yield achieved from each system



			SEASON							
System	System Description		Winter 15	Yield t/ha	Summer 15/16	Yield t/ha	Winter 16	Yield t/ha	Summer 16/17	Yield t/ha
Mixed Opportunity	Benchmark	Crop Sowing Date	Wheat *Gauntlet* *02-Jun-15*	5.3					Sorghum *Taurus* 11-Oct-16	6.2
	+nutrient supply	Crop Sowing Date	Wheat *Gauntlet* *02-Jun-15*	5.3					Sorghum *Taurus* 11-Oct-16	6.4
	+legume	Crop Sowing Date	Fababean *PBA Warda* *13-May-15*	4.6					Sorghum *Taurus* 11-Oct-16	6.2
	+crop diversity	Crop Sowing Date	Canola *45Y82CL* *14-May-15*	2.2					Sorghum *Taurus* 11-Oct-16	6.3
	+crop div. +nutrient	Crop Sowing Date	Canola *45Y82CL* *13-May-15*	2					Sorghum *Taurus* 11-Oct-16	6.0
	+crop div. +leg	Crop Sowing Date	Fieldpea *PBA Percy* *03-Jun-15*	2.4					Sorghum *Taurus* 11-Oct-16	6.5
	+cover crop /+leg	Crop Sowing Date	Chickpea *HatTrick* *14-May-15*	4					Sorghum *Taurus* 11-Oct-16	6.4
High intensity	+crop intensity	Crop Sowing Date	Wheat *Gauntlet* *13-May-15*	6	Mungbean *Jade* 23-Dec-15	0.4			Sorghum *Taurus* 11-Oct-16	5.6
	+crop inten. + nutrient	Crop Sowing Date	Wheat *Gauntlet* *13-May-15*	6.2	Mungbean *Jade* 23-Dec-15	0.5			Sorghum *Taurus* 11-Oct-16	5.5
	+crop inten. + leg	Crop Sowing Date	Fababean *PBA Warda* *13-May-15*	4.9	Mungbean *Jade* 23-Dec-15	0.4			Sorghum *Taurus* 11-Oct-16	3.9
	+crop inten. + crop div	Crop Sowing Date	Canola *45Y82CL* *14-May-15*	2.2	Mungbean *Jade* 23-Dec-15	0.7			Sorghum *Taurus* 11-Oct-16	4.5
	+crop inten. +crop div. + nut	Crop Sowing Date	Canola *45Y82CL* *13-May-15*	2.1	Mungbean *Jade* 23-Dec-15	0.7			Sorghum *Taurus* 11-Oct-16	5.5
	+crop inten. +crop div. + leg	Crop Sowing Date	Fieldpea *PBA Percy* *03-Jun-15*	2.5	Mungbean *Jade* 23-Dec-15	0.3			Sorghum *Taurus* 11-Oct-16	5.5
Summer-focussed	Benchmark	Crop Sowing Date	Wheat *Gauntlet* *02-Jun-15*	5.4					Maize *P727* *10-Oct-16*	2.9
	+nutrient supply	Crop Sowing Date	Wheat *Gauntlet* *02-Jun-15*	5.6					Maize *P727* *10-Oct-16*	3.4
	+legume	Crop Sowing Date	Fababean *PBA Warda* *13-May-15*	4.6					Maize *P727* *10-Oct-16*	3.8
	+crop diversity	Crop Sowing Date	Wheat *Gauntlet* *02-Jun-15*	5.7					Cotton *71483F* 10-Oct-16	
	+crop div. +nutrient	Crop Sowing Date	Wheat *Gauntlet* *02-Jun-15*	5.5					Cotton *71483F* 10-Oct-16	
	+crop div. +leg	Crop Sowing Date	Fababean *PBA Warda* *13-May-15*	4.8					Cotton *71483F* 10-Oct-16	
	+cover crop	Crop Sowing Date	Chickpea *HatTrick* *14-May-15*	3.6			Oat CC *18-Apr-16*		Sorghum *Taurus* 11-Oct-16	5.6
	- crop intensity	Crop Sowing Date			Maize *P727* *10-Oct-16*	7.1			Mungbean *Jade* 19-Jan-17	
Winter only	Benchmark	Crop Sowing Date	Wheat *Gauntlet* *02-Jun-15*	5.5			Chickpea *HatTrick* 01-Jul-16	3.6		
	+nutrient supply	Crop Sowing Date	Wheat *Gauntlet* *02-Jun-15*	5.4			Chickpea *HatTrick* 01-Jul-16	3.5		
	+legume	Crop Sowing Date	Fababean *PBA Warda* *13-May-15*	4.7			Wheat *Gauntlet* 01-Jul-17	6.2		
	+crop diversity	Crop Sowing Date	Canola *45Y82CL* *14-May-15*	2.3			Durum *Lillaroi* 01-Jul-16	7.7		
	+crop div. +nutrient	Crop Sowing Date	Canola *45Y82CL* *14-May-15*	2.3			Durum *Lillaroi* 01-Jul-16	7.8		
	+crop div. +leg	Crop Sowing Date	Fababean *PBA Warda* *13-May-15*	4.7			Durum *Lillaroi* 01-Jul-16	7.4		
	- crop intensity	Crop Sowing Date	Wheat *Gauntlet* *02-Jun-15*	5.8						

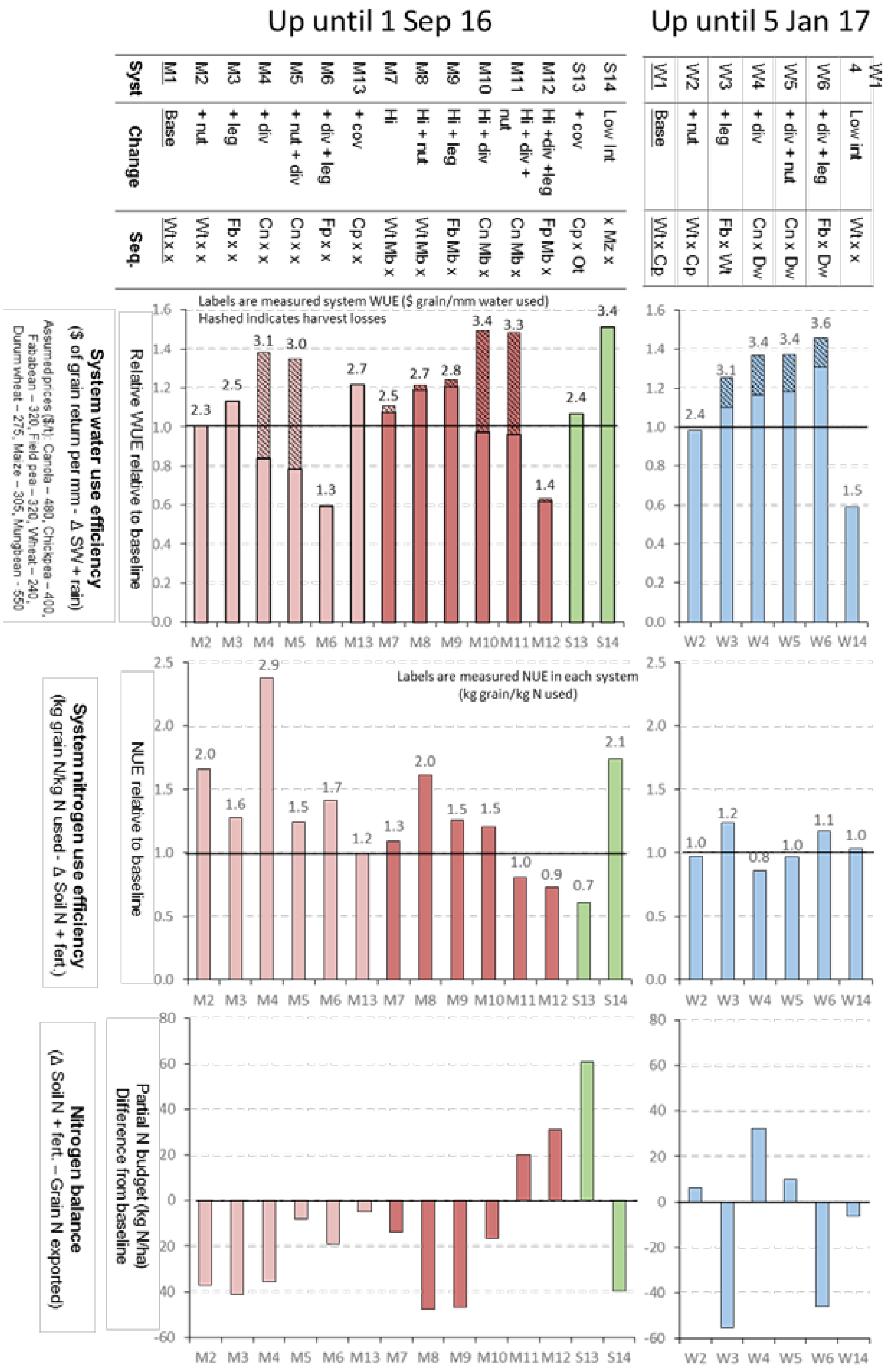


Figure 1. Effect of farming system modifications on system water use efficiency ($/ha/mm), nitrogen use efficiency (kg grain/kg N applied) and partial N balance over the first 1.5-2 years of the core experiment

Bars present the performance of each system modification relative to the baseline (1.0) within the mixed summer-winter crops or the winter-only crop systems; labels indicate the raw values. Above are indicated the system modification and the crop sequences that have been sown

Table 2. Impacts of previous crop on double cropped mungbean yields and disease incidence

Previous crop	Mungbean grain yield (t/ha)	Fusarium wilt incidence	*P. thornei* at sowing (#/g soil)	*P. thornei* at harvest (#/g soil)
Canola	0.81	39	8.4	13.6
Wheat	0.48	42	18.0	25.5
Fababean	0.44	55	13.8	24.7
Fieldpea	0.28	58	12.4	20.0

The third clear result is the effect that the previous mungbean crop had on reducing the grain yield of the subsequent sorghum crop by 0.5-0.8 t/ha compared to when a fallow was maintained over the same period (Table 1). Higher yield penalties were also observed in sorghum following faba bean and mungbean; this was attributed to residual Spinnaker® following the two legumes which impacted on sorghum establishment and growth.

System water use and nitrogen use efficiency

The capture and use of rainfall and the efficiency of N inputs are two key metrics which are being measured to compare the different production systems. Figure 1 compares these amongst various crop system treatments up until September 2016 and to January 2017 for the winter-only systems. Some clear differences in system water use efficiency (WUE) at this time were:

- If canola had been efficiently harvested this would have increased the system WUE by 30-40%
- The higher intensity systems have slightly higher WUE up until Sep 16, though the mungbean crop yields were low due to dry conditions during grain filling. The impacts on the subsequent sorghum crops have not been included here, but are likely to bring both systems back to similar system WUE.
- Field pea did not perform well at the site and hence lag behind the others in terms of systems water use efficiency. Significant benefits for subsequent crop productivity are required to make up for this shortfall.

In terms of nitrogen use efficiency (NUE) there are small differences amongst the winter-only crop systems, while differences in the mixed systems are larger. Several systems have higher NUE than the baseline system. The system involving canola had a high N use efficiency because it had significantly higher N mineralised following the previous crop than the other systems, including those involving legumes. The systems with legumes have not yet shown higher NUE as the legumes have also been relying on mineral soil N and have fixed little additional N; this is indicated by

Aerial view of Pampas trial site in 2015

Summer 2016/17 trials

the negative N balance where faba bean were grown. The higher intensity systems including the mungbean double crop had similar NUE to their equivalent low intensity systems which remained in fallow. Generally the systems with a higher NUE were those with a more negative N balance; only the three systems with NUE below the baseline system are those with higher relative N balance.

Implications for growers

So far this experiment has demonstrated that alternative crops like canola and durum wheat can have a positive impact on both nematode populations, subsequent grain yields without large negative impacts on system water or nitrogen use efficiency.

The impact of nematodes on reducing the grain yield of mungbean and propagating their populations demonstrates that double crops or two susceptible crops is high risk and should be avoided where nematode populations are significant. This, and the impact on subsequent crop yields, should be taken into account when assessing double crop options in the farming system.

Our systems have also demonstrated some of the complications with some systems such as managing residual herbicides and volunteer crops as weeds in subsequent crops (e.g. field pea).

Acknowledgements

This research is only possible with the funding and support of the Grains Research and Development Corporation (CSA00050), the CSIRO and the Department of Agriculture Fisheries, Queensland. Thank you also to our very helpful trial co-operators.

We would also like to specifically thank for their input and assistance, Paul MacIntosh, Pulse Australian and AHRI for assistance with herbicide recommendations on the systems, Jon Thelander, Seednet, Pacific Seeds and Pioneer for providing us with some of the trial seed, Wes Judd and Craig Antonio for help with cutting, conditioning and baling hay from pastures.

Staff at a field day, 2017

Weeds research

With the increase in glyphosate resistance and difficult to control weeds in the northern grains region (Queensland and New South Wales), a wider range of weed management tactics are required. One such tactic is the use of herbicides with of a wider range of mode of action by including residual herbicides into an integrated weed management strategy.

Residual herbicides are products that are applied to the soil and are absorbed by the germinating seedlings. This can therefore, provide medium to long-term control of weeds by controlling several flushes of emergence. The physical properties of residual herbicides varies by product (solubility, ultraviolet stability, stubble, soil binding etc.) as such efficacy can be affected by the environment in which it is applied (soil type, rainfall, temperature and ground cover). Hence, in order to better understand how different herbicides perform under varying conditions it is necessary to gather local efficacy and persistence data across a range of environments and seasons.

To gather this data, the Department of Agriculture and Fisheries research agronomy and weed science teams worked together to conduct residual herbicide trials on a range of soil types and climates across Queensland. In the summer of 2015-16 a range of herbicides were tested, both alone and in combination, at nine sites spread throughout Queensland cropping regions.

These sites targeted five major weeds:

- sow thistle (*Sonchus oleraceus*)
- feathertop Rhodes grass (*Chloris virgata*)
- awnless barnyard grass (*Echinochloa colona*)
- sweet summer grass (*Brachiaria eruciformis*)
- stink grass (*Eragrostis cilianensis*)

All of these weeds, except for stink grass, have had confirmed glyphosate resistant populations in the northern grains region. Stink grass, however, has had confirmed glyphosate resistance reported outside of Australia, so it is considered as a high risk weed. These datasets are intended to compliment the label for the individual herbicides. The herbicide label is a legal document, so should always be read prior to use and herbicides should only be applied as stated on the label.

To compliment this herbicide efficacy work, soil from each of these sites was collected to assess the impact of residual herbicides on soil biota, and their effect on subsequent plant growth in wheat and chickpeas.

In these trials efficacy varied between products, for level of control and duration of efficacy. There were also some species differences seen both within and between sites. In most cases the best control was achieved by mixing two active ingredients. Differences in impact on subsequent chickpea crops has been observed in biomass and nodule weight, and the assessment of microbial impact is ongoing. Another nine trials are being conducted in 2016-17 targeting sow thistle and will be reported in the next edition.

Contrast between residual herbicides and untreated control, with high densities of weeds germinating in the absence of herbicides

Feathertop Rhodes grass: efficacy of residual herbicides—Gindie

Darren Aisthorpe
Department of Agriculture and Fisheries

Research Questions: *How effective are residual herbicides in controlling feathertop Rhodes grass* (Chloris virgata)*? How long do residual herbicides provide effective control?*

Key findings

1. Combination treatments including Group B or Group D(1) performed best at this site on feathertop Rhodes grass.
2. Herbicides Flame®, Group D(1) and Group K(1) all showed good efficacy on their own, however could not match the combinations for overall efficacy.
3. Seedbank run down of feathertop Rhodes grass is very achievable with good residual herbicide choices and persistence to ensure no escaped plants produce additional seed.[1]

Background

Feathertop Rhodes grass (FTR) started becoming an issue in the late 1990s within the Dawson Callide region of Central Queensland (CQ), and has since spread across most farming areas of Queensland and northern New South Wales. It is highly adapted to zero till systems, as it will germinate very quickly from the soil surface or just below. The plant is inherently tolerant to the common knockdown herbicide glyphosate, so requires a well-timed double knock strategy to have any real success using this form of control strategy.

Difficulty controlling FTR with knockdown herbicides has pushed many growers back to using tillage to manage the grass instead of knockdown herbicide options. While this is an effective way of managing the growing or surviving plants, it does little to reduce the potentially large seed bank already in place.

Residual herbicides play an important role in an integrated weed management strategy for FTR. However incomplete efficacy and plant back data is available on some new and existing residual herbicides. The mode of action indicates how the herbicide effects the target plant; more information is available at www.croplife.org.au (search for 'mode of action').

To address this weed, as well as other broadleaf and grass weeds, three trials were established in CQ in 2015-16 summer (nine trials total in Queensland).

PLEASE NOTE:
Products and combinations in this field experiment were tested FOR RESEARCH PURPOSES ONLY.

Not all products used are registered for the purposes we have tested. Always read the label prior to use and only apply herbicides as approved in the label.

What was done?

The trial was established east of Gindie, or 50 km south east of Emerald, to evaluate over time, the control of different residual herbicides on weeds including feathertop Rhodes grass. Treatments were applied on 10 December 2015, laid out in a randomised block design; each plot was 10 m x 2 m with three replications of each. The product was applied using tapered flat fan nozzles at 2.2 bar and 4 km/hr to give very coarse to coarse droplets at a spray volume of 100 L/ha.

The site was dominated with a high density of FTR residue. Scattered dead and live plants of wild sunflower were also present along with residual sorghum stubble from the previous crop in the field which was harvested winter 2015. The treatment list (Table 1) includes herbicides covering a broad range of mode of action (MOA) groups.

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[1] The feathertop Rhodes grass IWM manual provides some guidance on how to achieve this goal. https://grdc.com.au/Resources/Publications/2014/11/Integrated-Weed-Management-of-Feathertop-Rhodes-Grass-2014

Table 1. Treatments applied at the Gindie site

Trt No.	MOA	Treatment	Rate (/ha)
1	-	Untreated control	-
2	B	Flame®	200 mL
3	D	Group D(1)	3.3 L
4	C	Terbyne® Xtreme®	1.2 kg
5	H	Balance® 750 WG	100 g
6	K	Group K(1)	2 L
7	B + H	Group B + Group H	200 mL + 100 g
8	B + K	Group B + Group K(1)	200 mL + 2 L
9	B + D	Group B + Group D(1)	200 mL + 3.3 L
10	D + H	Group D(1)+ Group H	3.3 L + 100 g
11	C	Group C triazine	1 kg
12	C	Group C urea	1 kg
13	G	Sharpen® WG	34 g
14	I	FallowBoss™ Tordon™	1 L
15	K	Group K(2)	1 L
16	D	Group D(2)	3 L

After treatment application, conditions turned very dry with little or no rainfall until late January. Conditions did improve for three weeks between late January and mid-February, however after this break, conditions returned to those similar to the November-December period, with isolated storms and hot dry conditions again.

Assessments were made on:

- 14 January 2016 (35 DAA)
- 27 January 2016 (48 DAA)
- 18 February 2016 (70 DAA)
- 5 April 2016 (117 DAA)

This site was planted by the grower to chickpea in early April to determine potential impact of the various treatments on a following crop. Crop emergence counts were made on 22 April 2016 approximately 10 days after planting.

At 88 days after application (DAA) soil samples were collected for evaluation of the impact of residual herbicides on subsequent crop growth and biological symbiotic associations (rhizobia and mycorrhiza), reported separately by Nikki Seymour (see page 199). After each emergence count the site was sprayed by backpack or tractor to eliminate any double counting or shadowing by older plants.

Results

An initial count and assessment was made on 14 January 2016 or 35 days after application (DAA). However when assessed for statistical difference, the low counts and variation between replicates meant that we were unable show to any significant difference between treatments.

The next assessment occurred on 27 January 2016 at 48 DAA. Analysis found there was a statistical difference between treatments (Figure 1).

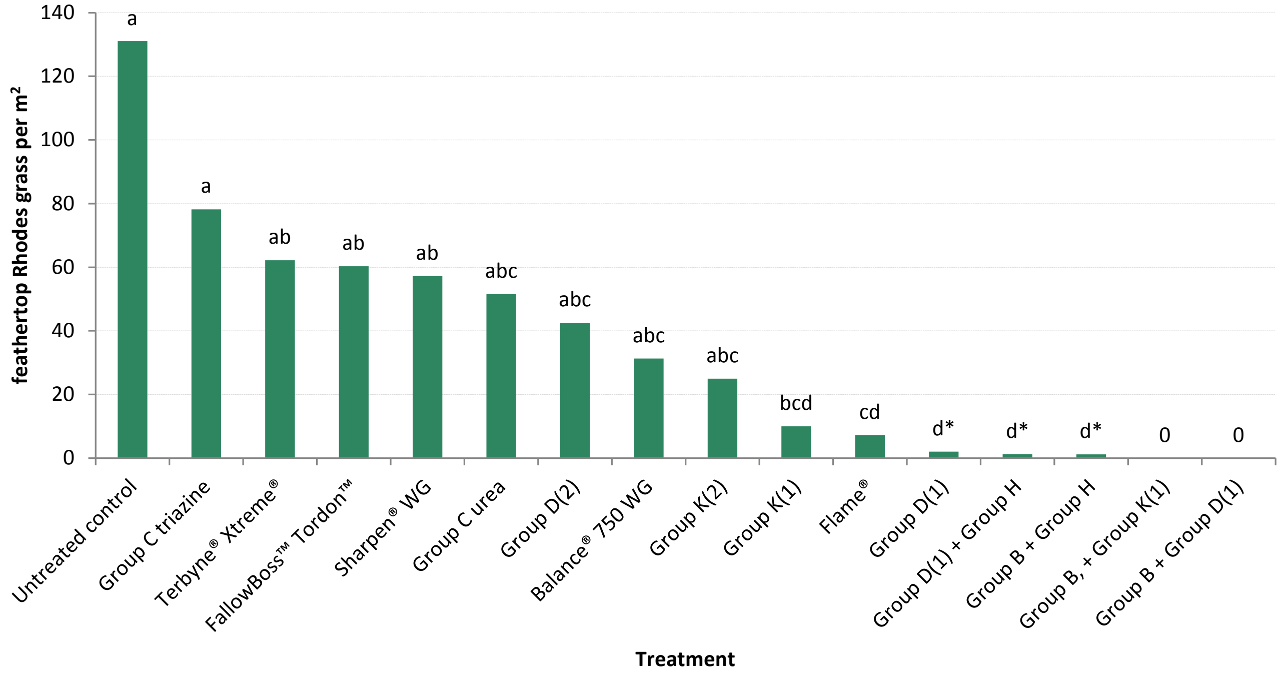

Figure 1: FTR seedlings per m² per treatment at 48 days after application

Columns with the same letter are not significantly different to each other (p 0.05). Columns with * are not significantly different to zero

Flame®, Group K(1), Group D(1) provided the greatest efficacy of the individual treatments, however it was the combination treatments which gave the highest efficacy to day 48 after application.

Two further assessments of weed germinations were made on 18 February and 5 April, however there were no other significant weed germinations of FTR seedlings or any other weeds. There was rain during this time, but it is suspected that the viable seed population on the surface may have been exhausted, given that all previous germinations were removed post count.

Implications for growers

This trial demonstrates that the fundamentals of residual herbicide work which was done in the past five years across Queensland still hold true. Group K(1), worked well then and continue to work now, as does Flame®, and Group D(1). However it was interesting to see the efficacy difference between the two group D products, given the good results which have been observed in earlier trials with Group D(2). Possibly the high ground cover from the residual FTR and temperatures post application may have caused this difference.

Feathertop Rhodes grass

The standout has been the combining of the already effective chemistries. Group B and Group D(1), and Group B and Group K(1) were the two lead treatments for this particular trial. With Group D(1) and the other combinations performing well also. This correlates well with the Gindie sweet summer grass site (page 180). The slightly higher rainfall received earlier, post application, may have assisted Balance® 750 WG based treatments to activate at this site, and have had a reasonable effect on germinating seedlings.

The clear message is that the combination of two different groups of herbicides has always performed better than any single product working on its own. With some persistence and attention to detail, seed banks can be greatly depleted quickly with the right products and follow-up to ensure no escapes.

Acknowledgements

Thank you to the site co-operators at Gindie. This project was co-funded by the Queensland Department of Agriculture and Fisheries (DAF) and the Grains Research and Development Corporation, and overseen by the DAF weeds team.

Trial details

Location:	Gindie
Crop:	Fallow
Soil type:	A poplar box/duplex soil located in the end of a paddock of Grey Vertosol. The original vegetation would have been flooded Coolabah/Brigalow, Belah and yellowwood
In-crop rainfall:	290 mm

Spraying out weeds after assessment

Feathertop Rhodes grass: efficacy of residual herbicides—Toobeah

Andrew Erbacher
Department of Agriculture and Fisheries

***Research Questions:** How effective are the residual herbicide in controlling feathertop Rhodes grass* (Chloris virgata)*? How long do the residual herbicides provide effective control?*

Key findings

1. The use of any residual herbicide reduced the feathertop Rhodes grass establishment for up to two months.
2. Group K and combinations of multiple herbicides provided the best short-term control.
3. Flame® provided the longest period of control, however there were a small number of weeds that were not controlled (escapes) at all assessment dates.

Background

The control of feathertop Rhodes grass (FTR) (*Chloris virgata*) is an issue across most farming areas of Queensland and northern New South Wales. It is highly adapted to zero till systems because it germinates very quickly from the soil surface. The plant is inherently tolerant to the most common knockdown herbicide, glyphosate, so growers require a well-timed double knock strategy (sequential spray applications with different modes of action) to have any real success in controlling FTR with knock-down herbicides.

Difficulty controlling FTR with knockdown herbicides has pushed many growers back to using tillage to manage the grass. While this is an effective way of managing growing or residual plants, it does little to reduce the potentially large seed banks that may already be in place.

Residual herbicides play an important role in an integrated weed management strategy for FTR. The document 'Integrated Weed Management of Feathertop Rhodes Grass 2014'[1] provides guidance on how to successfully control FTR, however efficacy and plant back data is incomplete for some new and existing residual herbicides.

Three trials were established on the Western Downs in the summer of 2015-16 (nine trials total in Queensland) to help increase local data on the efficacy and duration of control provided by these residual herbicides on FTR and other associated broadleaf and grass weeds. This paper reports one the trials near Toobeah in southern Queensland.

PLEASE NOTE:
Products/combinations in this field experiment were tested FOR RESEARCH PURPOSES ONLY.

Not all products used are registered for the purposes we have tested. Always read the label prior to use and only apply herbicides as approved in the label.

What was done?

The trial was established on a hard setting duplex soil, 45 km north-west of Goondiwindi. The paddock was long-fallowed out of sorghum, with patches of FTR grass established in-crop and the fallow prior to the trial. The paddock was worked prior to establishing the trial, providing a weed free surface with FTR stover visible in the high weed impacted areas.

Treatments were applied to 3 m x 10 m plots with three replicates on 22 December 2015, using a boom on a quad bike. The nine herbicide treatments (Table 1) were applied in 100 L/ha of water with an air-inducted coarse droplet size.

Table 1. Treatments applied

Trt No.	MOA	Product/s	Rate (/ha)
1	-	Untreated control	-
2	B	Flame®	200 mL
3	D	Group D	3.3 L
4	C	Terbyne® Xtreme®	1.2 kg
5	H	Balance® 750WG	100 g
6	K	Group K	2 L
7	B + H	Group B + Group H	200 mL + 100 g
8	B + K	Group B + Group K	200 mL + 2 L
9	B + D	Group B + Group D	200 mL + 3.3 L
10	D + H	Group D + Group H	3.3 L + 100 g

[1] https://grdc.com.au/~/media/Documents/Resources/Publications/Integrated-Weed-Management-Feathertop-Rhodes-Grass-2014-web-accessible.pdf

On 17 March (86 days after application; DAA) soil was collected and placed into cold storage for later use in pot trials to assess biological symbiotic associations (rhizobia and mycorrhiza); reported separately by Nikki Seymour (see page 199).

Established seedlings within fixed quadrats were counted approximately two weeks after each rainfall event, then sprayed out to prevent double counting and competition effects on later germination. Assessments were made on:

- 19 January (28 DAA)
- 17 February (57 DAA)
- 13 April (113 DAA)
- 30 May (160 DAA)

Results

Over the period 2-5 January (11-14 DAA) the site received 80 mm of rain resulting in a flush of FTR seedlings, which were assessed on 19 January (28 DAA) (Figure 1). All of the applied treatments reduced established populations relative to the 121 FTR per square metre established in the untreated control. The best performing treatments were Group K, Group D and the four combination treatments.

A second flush of weeds established as a result of 45 mm rain on 3-6 February (43-46 DAA) and was assessed on 17 February (57 DAA). The four combination treatments and Group K all had zero weeds establish at this time, in contrast to the untreated control that had 5.7 FTR per square metre. While there was no significant difference among the five treatments analysed, the untreated control was the only one with evidence of being different from zero.

Further smaller rainfall events in March saw a final assessment on 13 April (113 DAA) with 1.3 FTR per square metre counted in the untreated control. The Group B + Group D treatment had zero weeds for this assessment and were removed from the analysis. Although there was a significant difference among treatments analysed, none of the treatments were significantly better (i.e. with lower weed populations) than the untreated control by this stage. While not significantly different to the untreated control, Flame® (belonging to Group B) alone or in combination may still have provided some control at this time as the weeds numbers within these treatments were not significantly different to zero.

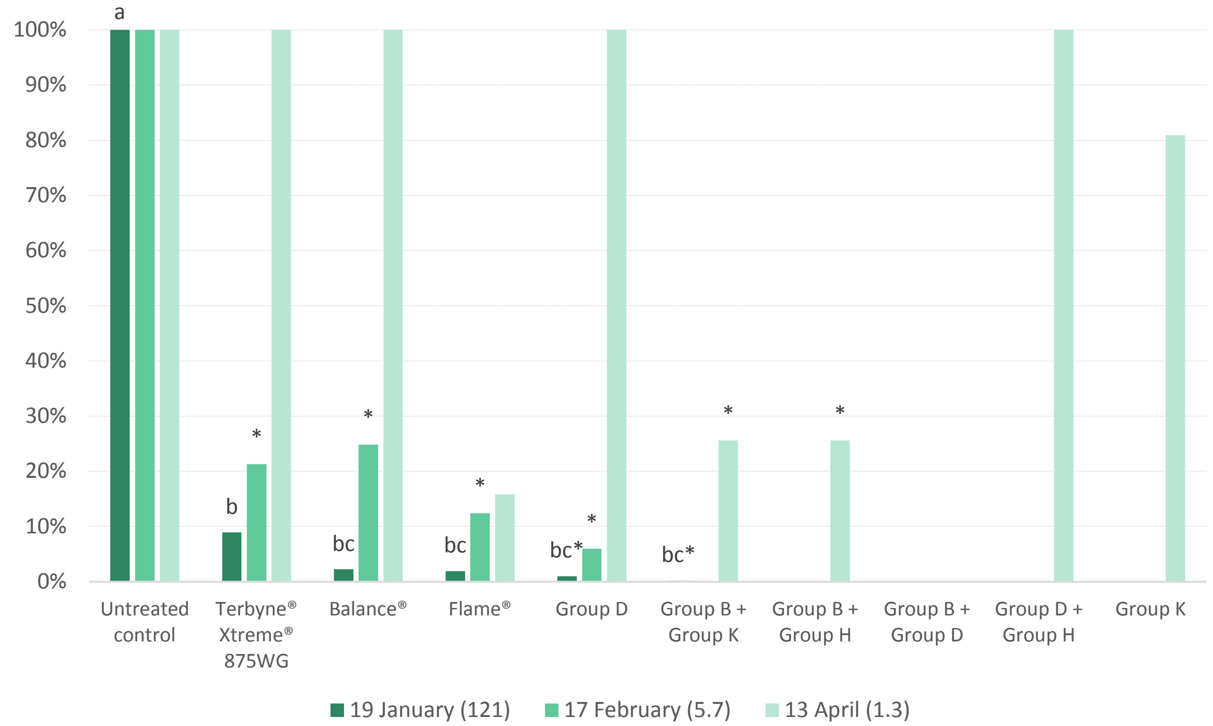

Figure 1. Emergence of feathertop Rhodes grass assessed 14-21 days after a significant rainfall event
Data is presented relative to the untreated control with back-transformed means of the untreated control for each assessment date. Average FTR germinations per square metre for the untreated control are provided in brackets. Columns within the same series (colour) with similar letters are not significantly different at the 5% significance level. Treatments with zero in all replicates were excluded from analysis. * = not significantly different from zero (p 0.05)

Implications for growers

All of the residual herbicides tested in this trial reduced the population of FTR established in the short-term.

The best standalone products for the first two months of this trial were Group D and Group K, while the four combination treatments provided equivalent control for this period. Combinations including Group B provided the longest period of FTR control, similar to Flame® on its own. However as a standalone product, Flame® had a small number of weeds that were not controlled (escapes) at all assessment dates.

Acknowledgements

Thank you to the site co-operators at Toobeah. This project was co-funded by the Queensland Department of Agriculture and Fisheries (DAF) and the Grains Research and Development Corporation, and was overseen by the DAF weeds team.

Trial details

Location:	Toobeah
Crop:	Fallow
Soil type:	Duplex
Trial rainfall:	120 mm

Demonstration of the resilience of feathertop Rhodes grass. A new germination and 'seedlings' setting seed at Toobeah FTR site on the 30 May assessment.

Sweet summer grass: efficacy of residual herbicides—Gindie

Darren Aisthorpe
Department of Agriculture and Fisheries

Research Questions: *How effective are residual herbicides in controlling sweet summer grass* (Brachiaria eruciformis)*? How long do residual herbicides provide effective control?*

Key findings

1. Using a combination of residual herbicides may offer greater control on a broader weed spectrum than a single product used in isolation.
2. Group D(1) and Group D(1) + Group B were the two best performing treatments.
3. The dry hot conditions post application appeared to have a significant negative effect on Balance® and Group C triazine efficacy, particularly early on in the trial.

PLEASE NOTE:
Products and combinations in this field experiment were tested FOR RESEARCH PURPOSES ONLY.

Not all products used are registered for the purposes we have tested. Always read the label prior to use and only apply herbicides as approved in the label.

Background

Residual herbicides play an important role in the control of summer weed species such as sweet summer grass . However, efficacy and plant back data on some new and existing residual herbicides is incomplete.

Sweet summer grass is a major weed in Central Queensland (CQ), requiring significant economic investment in its control, to the point where growers need to rotate out of summer cropping. Residual herbicides already play a significant role in its management, however after the confirmation of a glyphosate resistant population in the Central Highlands in 2014, the need to use a broad range of products with different modes of action (MOA) on the plant has become essential. The MOA indicates how the herbicide effects the target plant[1]. To address this weed, as well as other broadleaf and grass weeds, three trials were established in CQ in the 2015-16 summer (a total of nine trials were implimented in Queensland). An assessment of crop establishment is also planned for the next planting opportunity to validate plant back data.

What was done?

This trial was established at Ginide, 50 km south of Emerald, to evaluate the control by different residual herbicides on weeds including sweet summer grass and sowthistle over time.

The 15 herbicide treatments selected for the trials in CQ all had some known efficacy on some of the target species (Table 1).

This site potentially had two target weed seed banks present; sowthistle (*Sonchus oleraceus*) and sweet summer grass (*Brachiaria eruciformis*). There were also very low occurrences of wild sunflowers, both dead and alive at the time of application. The treatment list (Table 1) includes herbicides covering a broad range of MOA groups.

The herbicide treatments were applied on 11 December 2015, laid out in a randomised block design; each plot was 10 m x 2 m with three replications. The product was applied using tapered flat fan nozzles at 2.2 bar and 4 km/hr to give very coarse (VC) droplets at a spray volume of 100 L/ha.

Assessments were made in 2016 on:

- 14 January (35 DAA)
- 27 January (48 DAA)
- 18 February (69 DAA)
- 5 April (116 DAA)

After each weed emergence count the site was sprayed by backpack or tractor to eliminate any double counting or shadowing by older plants.

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[1] For further information see http://www.croplife.org.au/resistance-strategy/2016-herbicide-moa-table/

Table 1. Treatments applied at the Gindie site

Trt No.	MOA	Treatment	Rate (/ha)
1	-	Untreated control	-
2	B	Flame®	200 mL
3	D	Group D(1)	3.3 L
4	C	Terbyne® Xtreme®	1.2 kg
5	H	Balance® 750 WG	100 g
6	K	Group K(1)	2 L
7	B + H	Group B + Group H	200 mL + 100 g
8	B + K	Group B + Group K(1)	200 mL + 2 L
9	B + D	Group B + Group D(1)	200 mL + 3.3 L
10	D + H	Group D(1)+ Group H	3.3 L + 100 g
11	C	Group C triazine	1 kg
12	C	Group C urea	1 kg
13	G	Sharpen® WG	34 g
14	I	FallowBoss™ Tordon™	1 L
15	K	Group K(2)	1 L
16	D	Group D(2)	3 L

After treatment application, conditions turned very dry with little or no rainfall until late January. This site was planted by the grower to barley in early April to determine potential impact of the various treatments on a following crop. Crop emergence counts were made on 22 April 2016.

On 7 March 2016 (88 days after application; DAA) soil was collected and placed into cold storage for later use in pot trials to assess biological symbiotic associations (rhizobia and mycorrhiza), reported separately by Nikki Seymour (see page 199).

Results

The conditions at time of application (11/12/2015) through to late January were dry and hot; two key drivers for having less than ideal activation of the residual products applied. The only period of prolonged moist conditions was 151 mm from 2-7 February. This weed establishment was counted 11 days later at 69 DAA. As a result of the earlier hot, dry conditions both the Balance® treatment and the Group C traizine treatment showed limited efficacy by 69 DAA on weeds that had germinated.

Weed germinations were predominately sweet summer grass, despite the high sowthistle seed bank present. Sowthistle requires continuous wet conditions for two to three days for germination and unfortunately these requirements were not met.

An assessment of treatments was made 69 DAA (Figure 1). Treatments with common letters are not significantly different (p 0.05) from one another, despite having different mean plant counts per square metre.

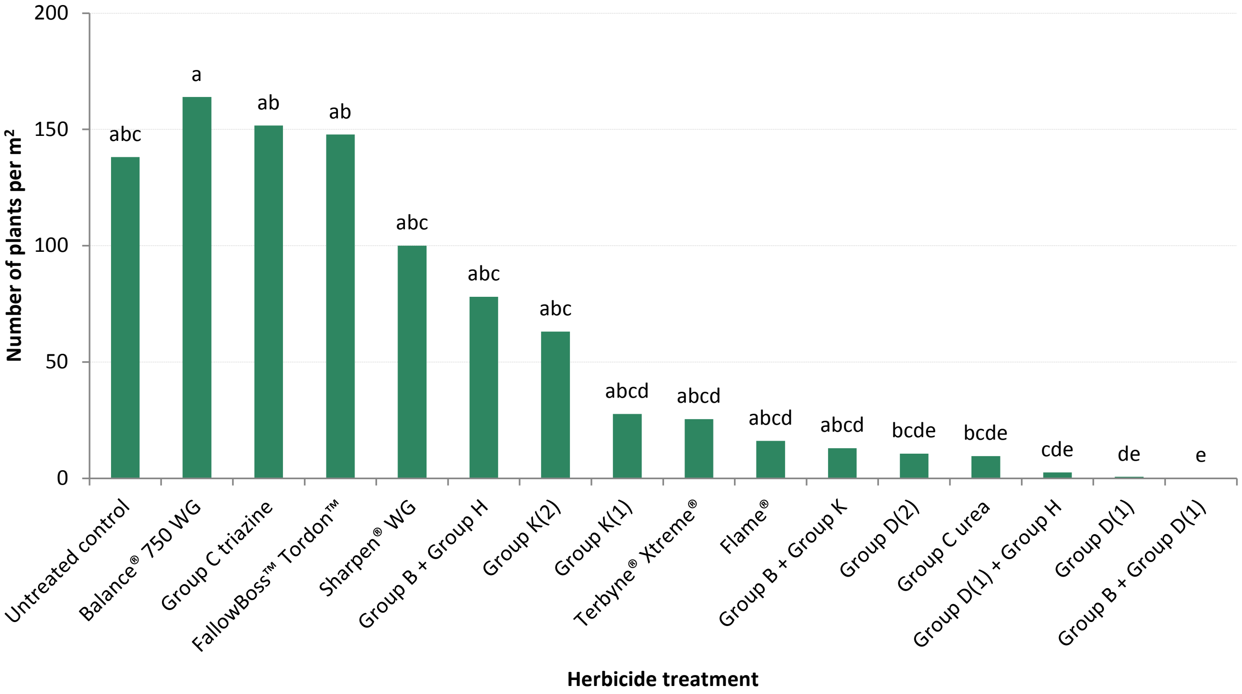

Figure 1. The accumulated mean count of SSG per m² per treatment on 18 February (69 days after application)

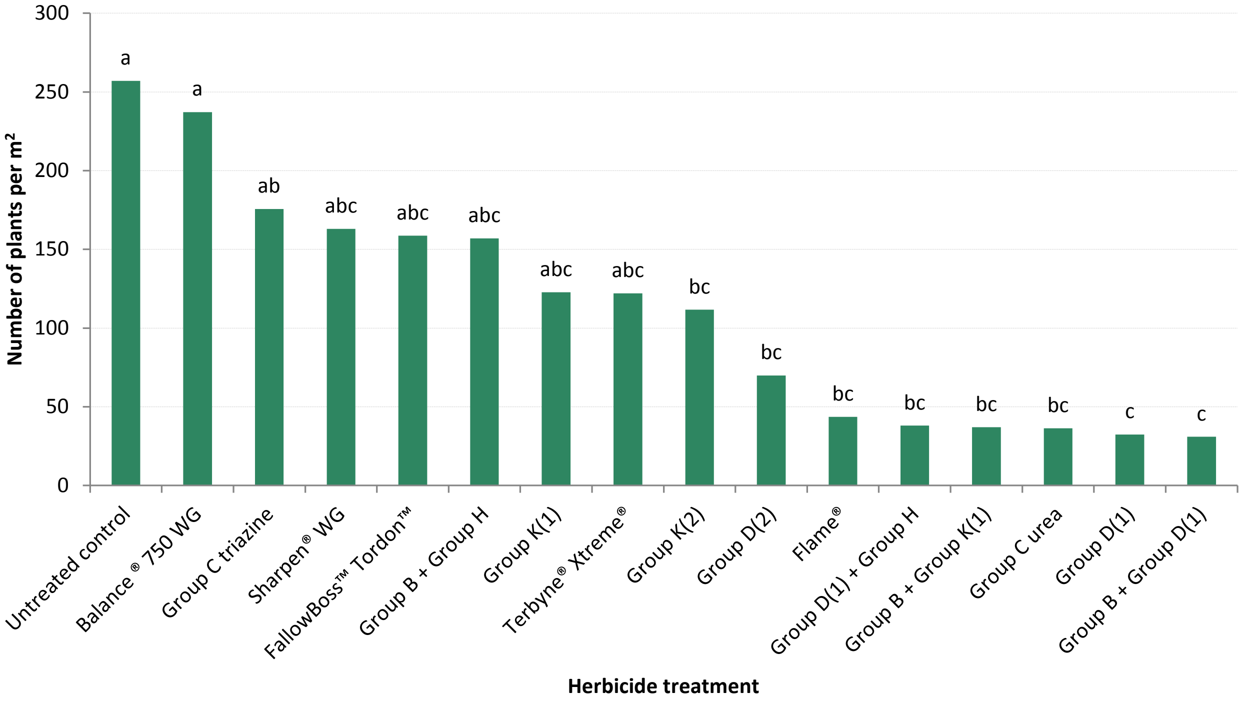

Figure 2: The accumulated mean count of SSG per m² per treatment on 5 April (116 days after application)

Residual treatments with MOAs within Groups D and C all showed good levels of efficacy; with the highest efficacy in the treatments containing Group Ds or Group C urea.

By 116 DAA, all products were starting to show signs of breaking down, however the Group D, Flame® and Group C urea treatments and three of the four combination treatments continued to offer a superior level of control (Figure 2).

On 22 April 2016, an establishment count was made on the barley which was planted into the trial field in mid-April. We were unable to establish any statistical difference between treatments, showing there was no reduction in crop establishment following any of the herbicide treatments.

Implications for growers

Group D(1)-based combinations appear to have the highest efficacy over the duration of the observations at the site, which included very hot and dry conditions initially, significant rainfall mid trial and dry conditions again towards the end. However, when you compare the accumulated mean plant counts of 69 DAA and 116 DAA, nearly all treatment counts increased by a similar amount, indicating that by the 70 day mark most products were beginning to reduce in efficacy.

Cropping programs and label requirements will always limit residual use patterns, however the results indicate that the combination of the Group D(1)and Group B would offer a broader spectrum of weed control than just Group D(1) and also reduce the pressure on a single formulation. The Group C urea treatment also performed well in the given conditions, but label limitations do significantly restrict application windows for this product.

Acknowledgements

Thank you to the site co-operators at Gindie. This project was co-funded by the Queensland Department of Agriculture and Fisheries (DAF) and the Grains Research and Development Corporation, and overseen by the DAF weeds team.

Trial details

Location:	Gindie
Crop:	Fallow
Cropping history:	The previous crop was chickpea in 2015, with a residual biomass from weeds present in the last crop obvious on the surface (10-15% ground cover)
Soil type:	Grey Vertosol open downs soil. Original vegetation would have been Queensland blue grass with broadleaf ironbark. The soil surface is a self-mulching clay, dry and zero tilled
In-crop rainfall:	290 mm

Stink grass: efficacy of residual herbicides—Goovigen

Darren Aisthorpe
Department of Agriculture and Fisheries

Research Questions: *How effective are residual herbicides in controlling stink grass? How long do the residual herbicides provide effective control?*

Key findings

1. The combination treatments were the best performing treatments, along with Group K(1).
2. Of the individual treatments, the two Group D formulations, Flame and Group K(1) gave the best efficacy.
3. Ground cover and incorporation of the products may have played a significant role in the efficacy of a number of treatments.

Background

Stink grass *(Eragrostis cilianensis)* ranks third behind feathertop Rhodes (FTR) and sweet summer grass as a grass weed of significance in Central Queensland (CQ). More commonly found in the Dawson Callide regions, the generally summer growing grass has a preference for the lighter alluvial soils. While not yet known to be resistant to common knockdown herbicide options such as glyphosate, some tolerance to Group A herbicides has been observed. The grass can be prolific in summer fallows and can swamp summer crops such as mungbeans or sorghum if not managed, which will inevitably put significant pressure on the current in-crop Group A options.

Incomplete efficacy and plant back data is available on some new and existing residual herbicides which may be suitable for this grass. To address this grass, as well as other broadleaves and grasses, three trials were established in CQ in 2015-16 summer (nine trials total in Queensland). The treatment list includes a broad range of products with different modes of action (MOA) on the target plant. The mode of action indicates how the herbicide affects the target plant[1].

It is also planned that after the next planting opportunity presented, some assessment of crop establishment could be made to validate plant back data.

PLEASE NOTE:
Products/combinations in this field experiment were tested FOR RESEARCH PURPOSES ONLY.

Not all products used are registered for the purposes we have tested. Always read the label prior to use and only apply herbicides as approved in the label.

What was done?

The trial was established 5 km east of Goovigen (40 km north west of Biloela) to evaluate, over time, the control of different residual herbicides on weeds including stink grass. Treatments were applied on the 15/12/2015, laid out in a randomised block design; each plot size was 10 m x 2 m with three replications of each. The product was applied using air inducted nozzles at 2.2 bar and 4 km/hr to give a very coarse to coarse droplet at a spray volume of 100 L/ha.

The site was fully cultivated, with no weeds, stubble or trash present, however it was very cloddy with surface crusting. Paddock history indicated that there may have been a wide range of weed seed present, including sowthistle, fleabane and grasses. The treatment list (Table 1) includes herbicides covering a broad range of MOA groups, selected to provide the opportunity to assess efficacy against a range of weeds.

Post-trial application, conditions turned very dry with little or no rainfall until late January. There was a period of rainfall in early February, however after this break, conditions generally returned hot and dry until planting rain arrived in late May/early June.

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[1] For further information see http://www.croplife.org.au/resistance-strategy/2016-herbicide-moa-table/

On 17 March (93 days after application; DAA) soil was collected and placed into cold storage for later use in pot trials to assess biological symbiotic associations (rhizobia and mycorrhiza); reported separately by Nikki Seymour (see page 199).

Table 1. Treatments applied at the Goovigen site

Trt No.	MOA	Treatment	Rate (/ha)
1	-	Untreated control	-
2	B	Flame®	200 mL
3	D	Group D(1)	3.3 L
4	C	Terbyne® Xtreme®	1.2kg
5	H	Balance® 750 WG	100 g
6	K	Group K(1)	2 L
7	B + H	Group B + Group H	200 mL + 100 g
8	B + K	Group B + Group K(1)	200 mL + 2 L
9	B + D	Group B + Group D(1)	200 mL + 3.3 L
10	D + H	Group D(1) + Group H	3.3 L + 100 g
11	C	Group C triazine	2 kg
12	C	Group C urea	1 kg
13	G	Sharpen® WG	34 g
14	I	FallowBoss™ Tordon™	1 L
15	K	Group K(2)	1 L
16	D	Group D(2)	3 L

Established seedlings within fixed quadrats were counted approximately two weeks after each rainfall event greater than 10mm, then sprayed out to prevent double counting and competition effects on later germination events.

Assessments were made on:

- 19 February (66 DAA)
- 22 June (190 DAA)

Results

Limited rainfall during the trial meant only one significant weed germination and count until the field was planted back to wheat in June. Between 28 January and 4 February, 235 mm of rainfall was received and a weed germination was counted on 19 February (66 DAA).

There were a broad range of weeds counted onsite in addition to stink grass, including calthrop, tar vine, black pigweed, wild sunflower, turnip, mexican poppy and phasey bean. However, establishment was scattered and thin, with insufficient numbers of any of these other weeds to find any significant difference in counts across the three replications at the site.

Stink grass constituted enough of the count to provide a significant difference between treatments (Figure 1). It is important to note that treatments with common letters are not significantly (0.05) different from one another, despite having different mean plant counts per square metre, when variability between replications is taken into account. The treatments without a letter above them had zero counts for all three replications.

The Group I and G products Fallowboss™ Tordon™ and Sharpen® provided no significant improvement over the nil treatments, and

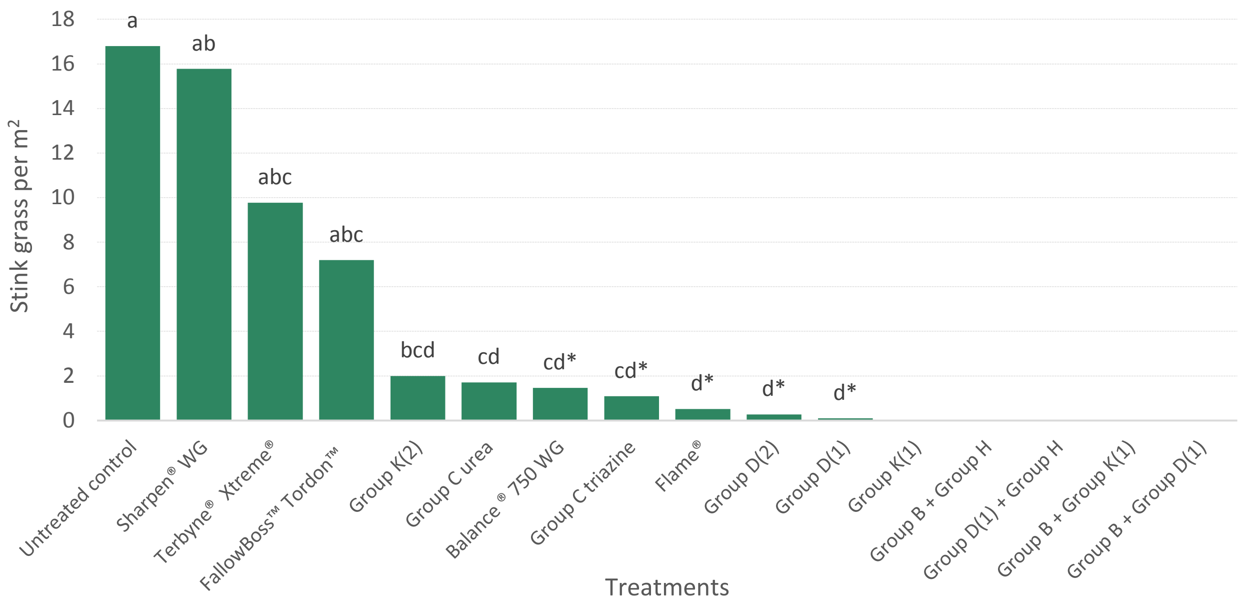

Figure 1. Emergence of stink grass assessed 66 days after application
Columns with similar letters are not significantly different at the 5% significance level. Treatments with zero in all replicates were excluded from analysis. * = not significantly different from zero (p 0.05)

interestingly in this scenario, the Group C product Terbyne® Xtreme® statistically also failed to perform any better than the untreated control.

The combination treatments provided complete control up to 66 DAA. This was not surprising given the level of control Flame®, Group D(1), Group D(2) and Group K(1) all provided individually (Figure 1). The Group D(2) result was interesting, when compared to its performance in the FTR trial at Gindie this year. In that trial there was a large amount of biomass to bind with and results suffered, where in this bare fallow field the significantly cheaper Group D product (Group D(2)) performed just as well as the more expensive Group D(1).

Given the weather conditions post application, it would not be unreasonable to suspect that the lack of any post application rain to incorporate and activate products like Terbyne® Xtreme® would have played a significant role in its failure to perform. However that should have been the same for the majority of the products applied, especially the Group D and Group K products, and yet some still seemed to have provided excellent control of the stink grass present.

Implications for growers

Consistent with the other two CQ trials; across a range of summer grasses; a combination of residual products, preferably with Flame® or Group D(1) in the mix, have performed best again in this trial. These treatments have also performed well individually, along with Group K(1), and show that the pressure put on our knockdown herbicides both in fallow and in-crop can be reduced using these products.

It does appear that residue load (or the lack of) may have had some influence in the efficacy of one or more of the products applied. Equally importantly, the need for rain (and/or tillage into moist soil) to incorporate and active some products also would have influenced the efficacy of some of the products applied. Under a different set of conditions which allowed for better incorporation by rain within seven days, it would have been very interesting to see what, if any differences would have occurred with respect to efficacy.

Acknowledgements

Thank you to the site co-operators at Goovigen. This project was co-funded by the Queensland Department of Agriculture and Fisheries (DAF) and the Grains Research and Development Corporation, and overseen by the DAF weeds team.

Trial details

Location:	Goovigen
Crop:	Fallow
Soil type:	Callide alluvial clay/silt. At time of application was cloddy, had surface crusting and low organic matter
Trial rainfall:	337 mm

Principal Technical Officer Maurie Conway sets up a 2 m shrouded boom ready for treatment application

Mature stink grass *(Eragrostis cilianensis)*

Summer grasses and broadleaf weeds: efficacy of residual herbicides—Kingaroy

Duncan Weir
Department of Agriculture and Fisheries

Research Questions: *How effective are different residual herbicides in controlling summer grasses and broadleaf weeds with specific focus on awnless barnyard grass and sow thistle? How long do residual herbicides provide effective control? What is the impact of residual herbicides on subsequent crop establishment?*

Key findings

1. Residual herbicides can provide important alternatives to knockdown herbicides.
2. Mixtures of herbicides of different modes of action have improved efficacy and the range of weeds controlled.
3. The knock-down herbicides Sharpen® WG and FallowBoss™ Tordon™ have provided short term residual control of broadleaf weeds.

Background

Fallow weed control plays a critical role in the management of cropping land prior to planting. Effective control can result in increased plant available water, higher levels of plant available nitrogen, a wider and more reliable planting window, reduced levels of insect pests, reduced levels of weed vectored diseases and nematodes and reduced physical impacts on planting and crop establishment (Cameron and Storrie 2014).

Herbicides have played a pivotal role in fallow weed management. Unfortunately long term, continual use of knockdown herbicides (e.g. glyphosate) has resulted in weeds such as awnless barnyard grass (*Echinochloa colona*), liverseed grass (*Urochloa panicoides*), sow thistle (*Sonchus oleraceus*) and fleabane (*Conyza bonariensis*) developing resistance. Residual herbicides are providing important alternatives to knockdown herbicides through their different modes of action (MOA). The MOA indicates how the chemical effects a plant and is an important method in grouping herbicides.

However, there is incomplete data on herbicide efficacy and plant back times on some of the new and existing products. Nine trials were established throughout Queensland to gather localised data on the efficacy and persistence of residual herbicides and residual herbicide combinations.

PLEASE NOTE:
Products /combinations in this field experiment were tested FOR RESEARCH PURPOSES ONLY.

Not all products used are registered for the purposes we have tested. Always read the label prior to use and only apply herbicides as approved in the Label.

What was done

This trial was established at Kingaroy Research Centre (KRC), Kingaroy Queensland, to evaluate, over time, different residual herbicides on weed control. Specific focus was given to awnless barnyard grass (Echinochloa colona) and sow thistle (Sonchus oleraceus). Treatments were applied on 26 February 2016, in a split block design with each main plot consisting of two adjacent plots (one treated and a nil treatment). There were 15 treatments (including an untreated control) replicated three times (Table 1). Each plot was 10 m long and 4 m wide, split into a 3 m treated area and a 1 m nil area. The nil treated area in each of the main plots was randomly placed on either side of the treated area.

The treatments were applied to bare soil using a quad bike mounted with a shrouded 3 m spray boom, preventing sidewards movement of herbicide sprays. The boom had Teejet AIXR 110015 nozzles 0.5 m apart, operated at a ground speed of 7 km/hr and a working pressure of three bar to give very coarse to coarse droplet size and 100 L/ha spray volume.

Table 1. Treatments applied at the Kingaroy Research Facility 2016 fallow herbicide trial site, including the herbicides' Mode of Action (MOA) and application rates

Trt No.	MOA	Product/s	Rate (/ha)
1	-	Untreated control	-
2	B	Flame®	200 mL
3	D	Group D(1)	3.3 L
4	C	Terbyne® Xtreme®	1.2kg
5	H	Balance® 750 WG	100 g
6	K	Group K	2 L
7	B + K	Group B + Group H	200 mL + 100 g
8	B + K	Group B + Group K	200 mL + 2L
9	B + D	Group B + Group D(1)	200 mL + 3.3 L
10	D + H	Group D(1) + Group H	3.3 L + 100 g
11	C	Group C triazine	2 kg
12	C	Group C urea	1 kg
13	G	Sharpen® WG	34 g
14	I	FallowBoss™ Tordon™	1 L
15	D	Group D(2)	3 L

As a consequence of not receiving predicted rainfall the site was irrigated (25 mm) on 1 March 2016 (four days after application—DAA) to assist herbicide incorporation. After each successful emergence and establishment of weeds, an assessment of populations was undertaken. Assessments were made on:

- 22 March 2016 (25 DAA)
- 19 April 2016 (53 DAA)
- 11 August 2016 (167 DAA)

Following each assessment the site was sprayed with Glyphosate 450®.

On 26 May 2016 (91 DAA) a 5 kg soil sample to a depth of 10 cm was taken from each plot. These samples were used as part of another project to evaluate the impact of the residual herbicide treatments on subsequent crop growth and biological symbiotic associations (rhizobia and mycorrhiza; see page 199).

Results

Low rainfall throughout the trial period had two impacts. It spread the germination period out making it very difficult to identify some plants at the time of assessment and, significantly reduced the number of weeds which established. Weeds were counted by species throughout the assessment processes but low numbers prevented them to be analysed individually. To allow meaningful analysis to be conducted, weeds were group into grass weeds and broadleaf weeds before analysis was done. Insufficient sow thistle plants were recorded to allow analysis and were included in the broadleaf weed group.

The main weeds identified throughout the trial included awnless barnyard grass (*Echinochloa colona*), barnyard grass (*Echinochloa crus-galli*), summer grass (*Digitaria* spp.), crows foot grass (*Cynosurus indica*), nut grass (*Cyperus rotundus*), couch grass (*Cynodon* spp.), bladder ketmia (*Hibiscus trionum*), caltrop (*Tribulus terrestris*), sow thistle (*Sonchus oleraceus*), dwarf amaranthus (*Amaranthus macrocarpus*), red pigweed (*Portulaca oleracea*), blue heliotrope (*Heliotropium amplexicaule*), annual ground cherry (*Physalis ixocarpa*) and turnip weed (*Brassica* spp.).

Significant differences (p 0.05) were achieved for both the grass weeds and broadleaf weeds at all three assessment times. Weed emergence numbers between the assessment dates differed greatly. In the untreated control, weed counts were one plant/m^2 on 22 March; 6.5 plants/m^2 on 19 April; and 2.8 plants/m^2 on 11 August 2016.

Application of herbicide treatments, Kingaroy Research Facility 2016

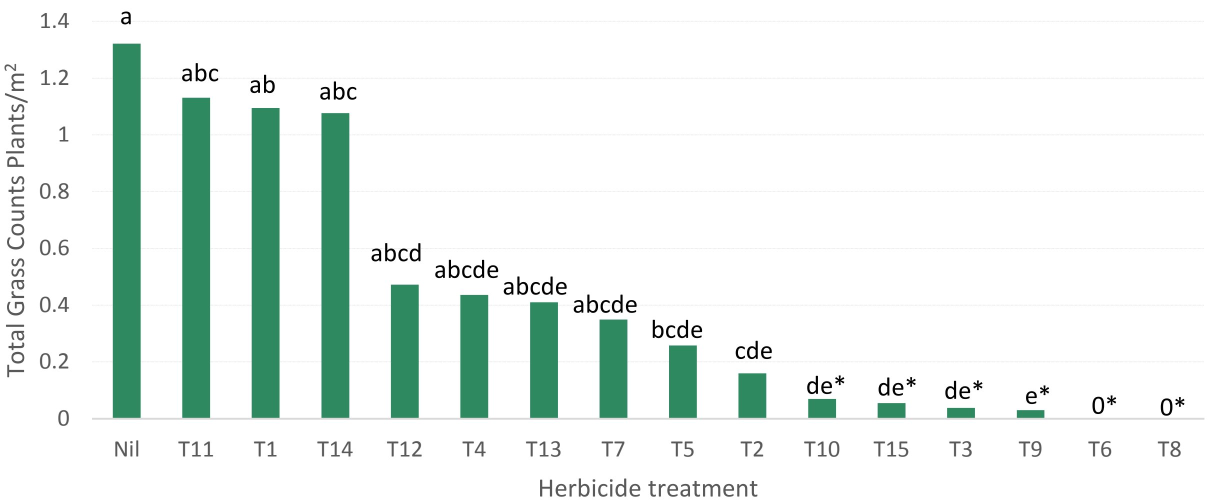

Figure 1. Total grass counts established/m² follwing assessment on 19 April 2016

Values with similar letters are not significantly different (p 0.05). Treatments with zero in all replicates were removed from the anaysis. *= not significantly different from zero weed count treatments (p 0.05)

Total grass weeds

Following grass counts on 22 March 2016, T6 was found to have zero grass across all three replications and were removed to allow statistical analysis. Four treatments (T3, T7, T8 and T15) were found to have significantly less grass established than the nil and untreated control treatments but not significantly different from zero.

Following the assessment of grass counts on 19 April 2016, T6 and T8 were found to have zero grass counts across all three replications and were removed to allow statistical analysis. Five treatments (T2, T3, T9, T10 and T15) were found to be significantly different (p 0.05) from the nil and untreated control treatments (Figure 1) but not significantly different from zero.

Total broadleaf weeds

Following broadleaf counts on 23 March 2016 T13 was found to have zero broadleaf weeds across all three replications so was removed to allow statistical analysis. Four treatments (T3, T7, T9 and T14) were found to be significantly different (p 0.05) from the untreated control (T1) and nil treatments.

Following broadleaf counts on 19 April 2016, 10 treatments were found to be significantly different (p 0.05) from the nil and T1-untreated control treatments. The best performing treatments at this date were; T2, T4, T7, T8 and T9 (Figure 2).

Assessments conducted on 11 August 2016 found four treatments (T2, T8, T7, and T9) to be significantly better than T1 untreated control and nil treatments (Figure 3).

Implications for growers

Residual herbicides can provide important alternatives to knockdown herbicides such as glyphosate. This trial demonstrates that effective weed control can be achieved in fallow rotations using residual herbicides for up to 167 days.

Sharpen® WG and FallowBoss™ Tordon™ have provided short-term residual control of broadleaf weeds, but have had little effect on the grass weeds present.

Both treatments with stand-alone Group D products (T3 and T15) provided good grass weed control out to 53 DAA, however T3-Group D(1) was much more effective on the broadleaf weeds present. Similarly, the two Group K treatments (T6 and T8) have provided effective grass weed control for 53 DAA, but without a mixing partner (T6) has reduced control of broadleaf weeds.

The four treatments with multiple MOA (T7, T8, T9 and T10) have consistently provided high levels of control on grass weeds, however T10-Group D(1)+Group H has performed poorly for broadleaf weeds. The three treatments that include Group B as part of a mixture (T7, T8, T9) consistently showed significantly better weed control (grasses and broadleaf) than most other treatments, and together with T2-Flame® were still providing control 167 DAA.

Acknowledgements

This project was co-funded by Department of Agriculture and Fisheries (DAF) and the Grains Research and Development Corporation, and overseen by the DAF weeds team.

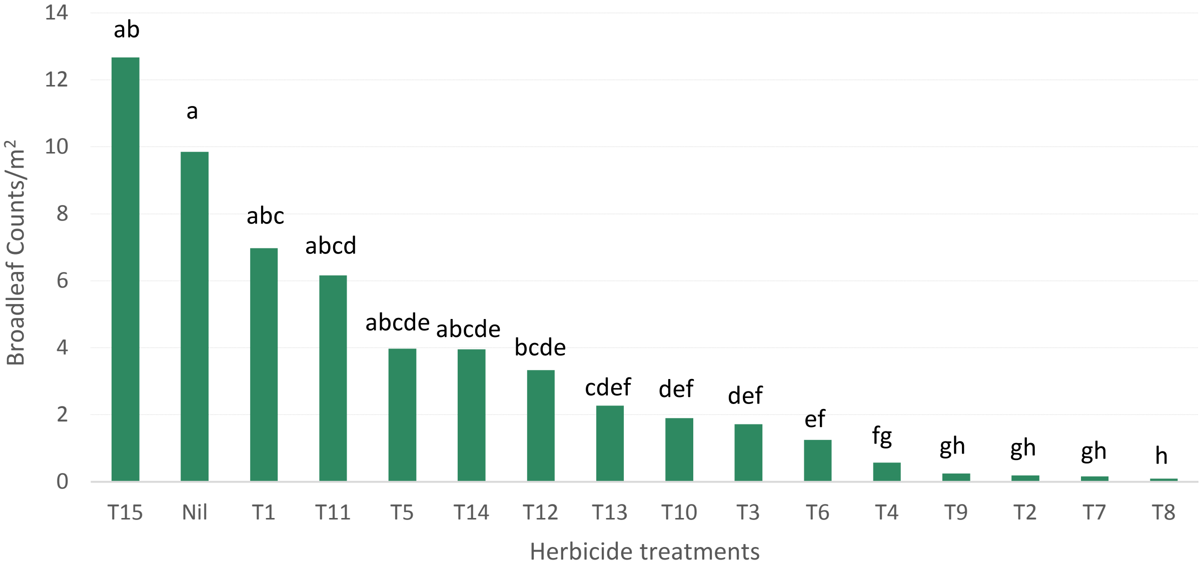

Figure 2. Total broadleaf counts established/m² follwing assessment 19 April 2016
Values with similar letters are not significantly different (p 0.05)

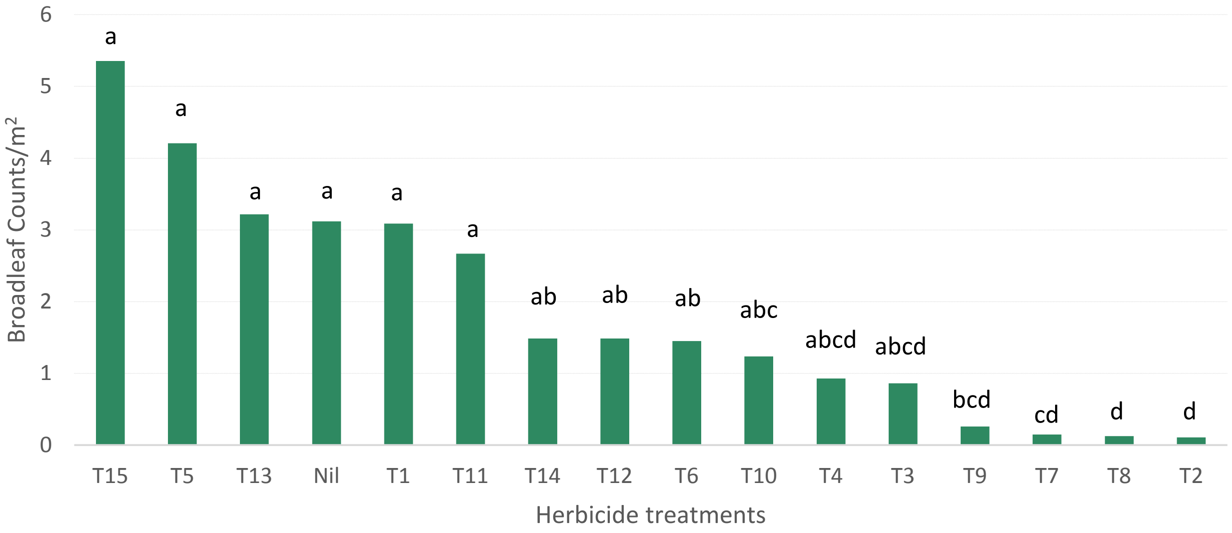

Figure 3. Total broadleaf counts established/m² follwing assessment 11 August 2016
Values with similar letters are not significantly different (p 0.05)

Trial details

Location:	Kingaroy Research Facility
Crop:	Fallow
Soil type:	Red Ferrosol
In-crop rainfall:	74 mm

Further reading

Cameron, J. and Storrie, A. 2014, *Summer fallow weed management. A reference manual for grain growers and advisers in the southern and western grains regions of Australia*. Grains Research and Development Corporation.

Weed establishment in a control treatment plot, Kingaroy Research Facility 20/4/2016

Summer grasses and sowthistle: efficacy of residual herbicides—Warwick

Duncan Weir
Department of Agriculture and Fisheries

Research Questions: *How effective are different residual herbicides in controlling summer grasses and broadleaf weeds with specific focus on awnless barnyard grass and sow thistle? How long do residual herbicides provide effective control? What is the impact of residual herbicides on subsequent crop establishment?*

Key findings

1. Effective weed management in fallow rotations can be achieved using residual herbicides.
2. Efficacy of residual herbicides can be influenced by weather conditions.

Background

Fallow weed control plays a critical role in the management of cropping land prior to planting. Effective control can result in increased plant available water, higher levels of plant available nitrogen, a wider and more reliable planting window, reduced levels of insect pests, reduced levels of weed vectored diseases and nematodes and reduced physical impacts on planting and crop establishment (Cameron and Storrie 2014).

Herbicides have played a pivotal role in fallow weed management. Unfortunately long term, continual use of knockdown herbicides such as glyphosate has resulted in weeds such awnless barnyard grass (*Echinochloa colona*), liverseed grass (*Urochloa panicoides*) and fleabane (*Conyza bonariensis*) developing resistance. Residual herbicides are providing important alternatives to knockdown herbicides through their different modes of action (MOA). The MOA indicates how the chemical effects a plant and is an important method in grouping herbicides.

There is however incomplete data on herbicide efficacy and plant back times on some of the new and existing products. Nine trials were established throughout Queensland to gather localised data on the efficacy and persistence of residual herbicides and residual herbicide combinations.

PLEASE NOTE:
Products /combinations in this field experiment were tested FOR RESEARCH PURPOSES ONLY.

Not all products used are registered for the purposes we have tested. Always read the label prior to use and only apply herbicides as approved in the Label.

What was done

This trial was established at Hermitage Research Station (HRS), Warwick, Queensland, to evaluate over time, the control of different residual herbicides on weeds including awnless barnyard grass (*Echinochloa colona*) and sow thistle (*Sonchus oleraceus*). Treatments were applied on 25 February 2016, in a split block design with each main plot consisting of two adjacent plots (one being a nil treatment). There were 16 treatments replicated three times (Table 1). Each plot was 10 x 4 m, split into a 3 m treated area and a 1 m untreated (nil area). The nil treated area in each of the main plots was randomly placed on either side of the treated area.

The treatments were applied to bare soil using a quad bike mounted with a shrouded 3 m spray boom, preventing sidewards movement of herbicide sprays. The boom had Teejet AIXR 110015 nozzles 0.5 m apart, was operated at a ground speed of 7 km/hr and a working pressure of three bar to give a droplet size of very coarse to coarse and spray volume of 100 L/ha.

Table 1. Treatments applied at the Hermitage Research Station fallow herbicide trial site

Trt No.	MOA	Treatment	Rate (/ha)
T1	-	Untreated control	-
T2	B	Flame®	200 mL
T3	D	Group D(1)	3.3 L
T4	C	Terbyne® Xtreme®	1.2kg
T5	H	Balance® 750 WG	100 g
T6	K	Group K(1)	2 L
T7	B + H	Group B + Group H	200 mL + 100 g
T8	B + K	Group B + Group K(1)	200 mL + 2L
T9	B + D	Group B + Group D(1)	200 mL + 3.3 L
T10	D + H	Group D(1) + Group H	3.3 L + 100 g
T11	C	Group C triazine	1 kg
T12	C	Group C urea	1 kg
T13	G	Sharpen® WG	34 g
T14	I	FallowBoss™ Tordon™	1 L
T15	K	Group K(2)	1 L
T16	D	Group D(2)	3 L

As a consequence of not receiving predicted rainfall the site was irrigated (32 mm) on 1 March 2016 (4 days after application—DAA) to assist herbicide incorporation. After each successful emergence and establishment of weeds, an assessment of populations was undertaken.

Assessments were made on:

- 23 March 2016 (27 DAA)
- 22 April 2016 (57 DAA)

Following each assessment the site was sprayed with Glyphosate 450®.

On 25 May 2016 (88 DAA) a five kilogram soil sample to a depth of 10 cm was taken from each plot. These samples were used as part of another project (reported on page 199) to evaluate the impact of the residual herbicide treatments on subsequent crop growth and biological symbiotic associations (rhizobia and mycorrhiza).

Wheat, barley and chickpea were planted across all treatments on 1 August 2016 to assess the impact these herbicides had on subsequent crop establishment. Plant establishment counts were taken on 30 August 2016.

Results

Rainfall throughout the trial period was well below average and ineffective. A total of 17.6 mm of rainfall was received following the initial irrigation and before the first assessment. Another 45.8 mm of rainfall was received before the second assessment was taken. Weed emergence was staggered over a long period of time making identification of very small weeds difficult. In these cases the seedlings were grouped as either a grass or a broadleaf. The trial received only 22.4 mm of rain over the April and May period and combined with cooler temperatures there wasn't any further germination of summer weeds.

A variety of weeds were identified. The grass was awnless barnyard grass (*Echinochloa colona*) and the main broadleaf weeds included: sow thistle (*Sonchus oleraceus*), bladder ketmia (*Hibiscus trionum*), caltrop (*Tribulus terrestris*), caustic creeper (*Chamaesyce drummondii*), dwarf amaranthus (*Amaranthus macrocarpus*) and red pigweed (*Portulaca oleracea*).

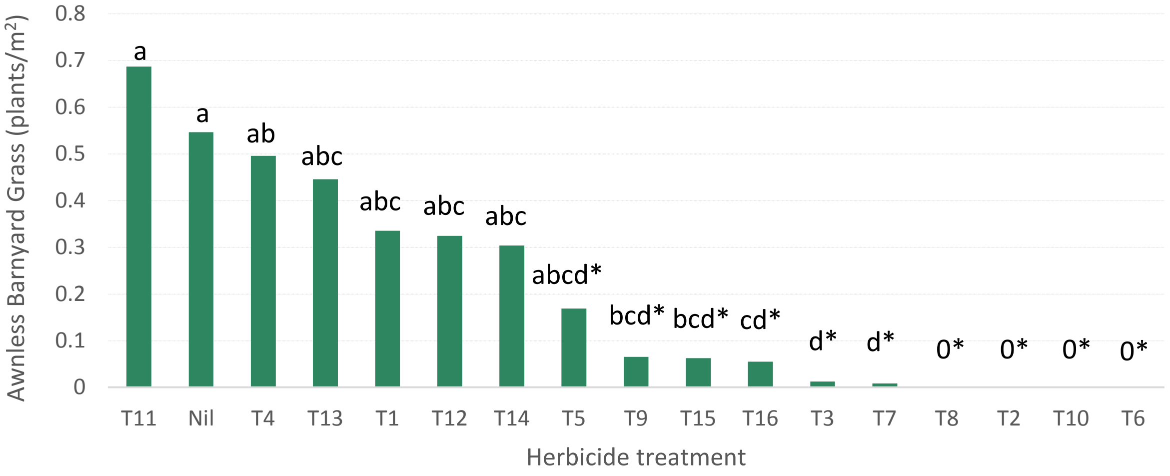

Figure 1. Awnless barnyard grass seedlings established/m²–April 2016

Values with similar letters are not significantly different (p 0.05). Treatments with zero in all replicates were removed from the analysis. * = not significantly different to zero weed count treatments (p 0.05)

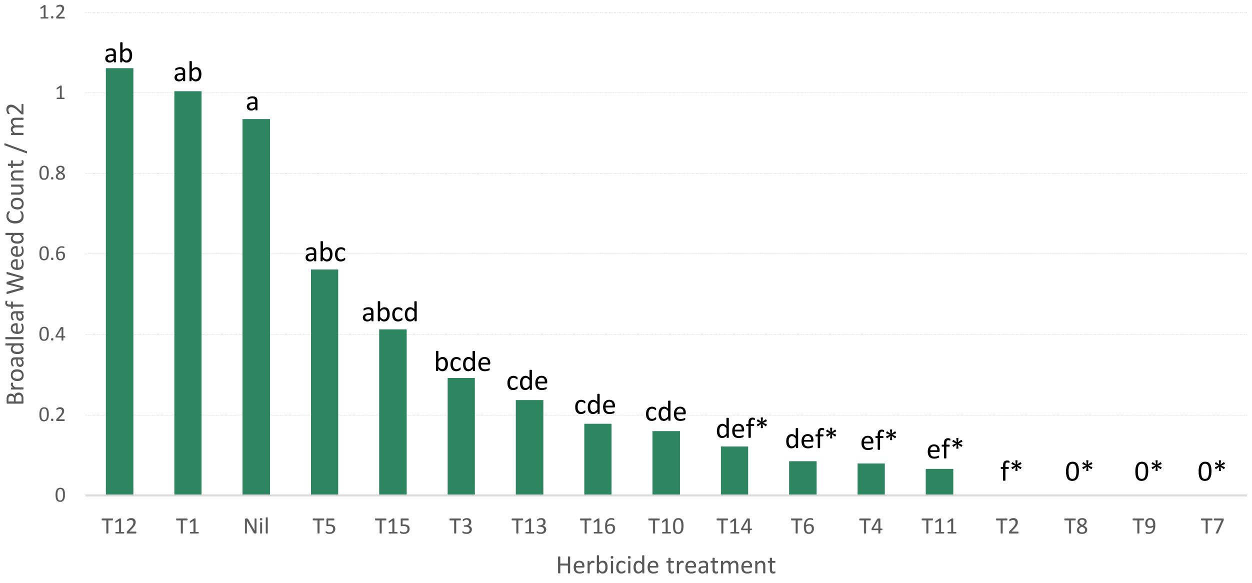

Figure 2. Broadleaf weed seedlings established/m²–April 2016

Values with similar letters are not significantly different (p 0.05). Treatments with zero in all replicates were removed from the analysis. * = not significantly different to zero weed count treatments (p 0.05)

Awnless barnyard grass

No significant results were achieved following the assessment on the 23 March 2016. Low levels of awnless barnyard grass were measured however plant numbers were not sufficient to identify treatment effects.

The weed assessment on 22 April 2016 resulted in four treatments (T2, T6, T8 and T10) with zero weed counts across all three replications and were removed to allow statistical analysis. Five treatments (T3, T7, T9, T15 and T16) have shown significant difference (p 0.05) from the untreated control (T1) and the nil treatments (Figure 1), and were also not significantly different to zero.

Broadleaf weeds

Too few sow thistle plants were counted in either of the two assessments for analysis to be undertaken. As a result all broadleaf weeds were assessed together.

Assessments taken on 23 March 2016 found that two herbicide treatments (T7 and T8) had zero weeds across all three replications and were removed to allow statistical analysis. Two treatments (T2 and T9) were not significantly different to zero. Four treatments (T2, T5, T9 and T14) were found to be significantly different (p 0.05) from the T1 untreated control and nil treatments.

Assessments taken 20 April 2016 found three treatments (T7, T8 and T9) had zero weeds across all three replications and were removed to allow statistical analysis. Five treatments (T2, T4, T6, T11 and T14) were significantly different (p 0.05) from T1 and nil treatments and not significantly different to zero.

A further three treatments (T10, T13, and T16) also had significantly (p 0.05) reduced established weeds populations relative to T1 and nil treatments (Figure 2), but were not as effective as the best group of eight treatments (T2, T4, T6, T7, T8, T9, T11 and T14).

Plant back

There weren't any plant population differences recorded for wheat and barley across all treatments, however T12 – Group C urea did significantly impact chickpea with all emerging seedlings either dying or were extensively deformed, when planted 158 DAA.

Implications for growers

Residual herbicides can provide important alternatives to knockdown herbicides such as glyphosate. This trial demonstrates that effective weed control can be achieved in fallow rotations using residual herbicides for up to 57 days. Flame® (T2) has shown to be effective on a range of grass and broadleaf weeds. However T7, T8 and T9 have also shown to be as effective (if not more effective), as they have the added benefit of combining two modes of action, reducing the pressure on one chemical alone.

Effective rainfall has influenced weed emergence and treatment efficacy in the trial. Rainfall and weather conditions can influence the rate at which herbicides are broken down and need to be considered before planting the following crop.

Acknowledgements

This project was co-funded by Department of Agriculture and Fisheries (DAF) and the Grains Research and Development Corporation, and overseen by the DAF weeds team.

Trial details

Location:	Hermitage Research Station
Crop:	Fallow
Soil type:	Cracking Black Vertosol
In-crop rainfall:	32 mm irrigation, 63.4 mm rainfall

References and further reading

Cameron, J. and Storrie, A. 2014, *Summer fallow weed management. A reference manual for grain growers and advisers in the southern and western grains regions of Australia*. Grains Research and Development Corporation.

Congreve, M. and Cameron, J. 2015, *Soil behaviour of pre-emergent herbicides in Australian farming systems, a reference manual for agronomic advisors*. Grains Research and Development Corporation.

Treatment application

Residual herbicide trial replant to wheat, barley and chickpea

Awnless barnyard grass: efficacy of residual herbicides—Toobeah

Andrew Erbacher
Department of Agriculture and Fisheries

***Research Questions:** How effective are different residual herbicides in controlling awnless barnyard grass (*Echinochloa colona*), and how does this change over time? What is the impact of residual herbicides on subsequent crop establishment?*

Key findings

1. The use of most residual herbicides tested have reduced the population of awnless barnyard grass established.
2. Twelve treatments provided high levels of control of awnless barnyard grass to 28 days.

PLEASE NOTE:
Products/combinations in this field experiment were tested FOR RESEARCH PURPOSES ONLY.

Not all products used are registered for the purposes we have tested. Always read the label prior to use and only apply herbicides as approved in the label.

Background

Awnless barnyard grass (ABYG) is an annual weed that is common to summer fallow paddocks in southern Queensland and northern New South Wales. It will germinate and establish in multiple cohorts in a season, but the first germination in spring is typically the largest. These spring germinations are often from storm rain and the weeds then stress quickly as the soil dries; it can be difficult to control the stressed weeds with translocated systemic herbicides such as glyphosate.

Furthermore, surveys in 2007 identified approximately 100 populations of ABYG with group M (glyphosate) resistance. To combat this increasing resistance, residual herbicides can be used as part of an integrated weed management (IWM) program, to provide a wider range of modes of action (MOA) and so reduce the population of weeds that need to be controlled by other tactics (such as crop competition, knock-down herbicides and tillage).

However, there is incomplete efficacy and plant back data on some new and existing residual herbicides that may be suitable for ABYG. Three trials were established on the Western Downs over the 2015-16 summer (nine trials total in Queensland) to help increase local data on the efficacy and duration of control provided on ABYG and other associated broadleaf and grass weeds. This paper reports on one of the trials near Toobeah in southern Queensland.

What was done

The trial was established on a red ironstone patch in a Grey Vertosol brigalow soil, 30 km north of Toobeah (65 km NW of Goondiwindi). The paddock had a large population of sowthistle and ABYG in the 2014 wheat crop and subsequent fallow, and was planted to chickpea in 2015. The paddock was blade ploughed to control mature weeds prior to the application of a range of herbicide options likely to control both of the dominant weeds in this paddock (Table 1).

The treatments were applied to small plots (3 m x 10 m) with three replicates on 22 December 2015 using a boom on a quad bike. The 15 herbicide treatments were applied in 100 L/ha of water with an air inducted extra coarse (XC) droplet size.

On 17 March (86 days after application; DAA) soil was collected and placed into cold storage for later use in pot trials to assess biological symbiotic associations (rhizobia and mycorrhiza); reported separately by Nikki Seymour (see page 199).

Established weed seedlings within fixed quadrats were counted approximately two weeks after each rainfall event; then sprayed out to prevent double counting and competition effects on later germination events.

Assessments were made on:

- 19 January (28 DAA)
- 17 February (57 DAA)
- 30 May (160 DAA)

Table 1. Treatments applied at the Toobeah site

Trt No.	MOA	Product/s	Rate (/ha)
1	-	Untreated control	-
2	B	Flame®	200 mL
3	D	Group D(1)	3.3 L
4	C	Terbyne® Xtreme® 875	1.2 kg
5	H	Balance® 750WG	100 g
6	K	Group K(1)	2 L
7	B + K	Group B + Group H	200 mL + 100 g
8	B + K	Group B + Group K(1)	200 mL + 2 L
9	B + D	Group B + Group D(1)	200 mL + 3.3 L
10	D + H	Group D(1) + Group H	3.3 L + 100 g
11	C	Group C triazine	2 kg
12	C	Group C urea	1 kg
13	G	Sharpen® WG	34 g
14	I	FallowBoss™ Tordon™	1 L
15	K	Group K(2)	1 L
16	D	Group D(2)	3 L

Results

Conditions were hot and dry for the period of the trial. Five DAA, the site received 15 mm of rain over three days, followed by 83 mm for the period 03-07 January (12-16 DAA). This rainfall event triggered a germination of awnless barnyard grass, which was assessed on 19 January (28 DAA). There were four treatments that had no ABYG, and a further eight that had populations not significantly different to zero (Figure 1). While these results are unable to discern differences between many of the products, the best 12 treatments applied have achieved 95% or better reductions in ABYG established.

The other rainfall events during the life of the trial resulted in minor germination events with populations measured in the Untreated Control too variable to discern significant differences from the treated plots.

There were no visible symptoms of herbicide damage in the June planted wheat crop at the time of establishment counts. Wheat populations were a healthy 95 plants/m² across all plots.

Implications for growers

The results from this trial clearly show there are a number of products and combinations that provided effective control of ABYG in the short term. Dry conditions over summer resulted in variable germinations in this trial, but other trials within this series have demonstrated differences between treatments from later germination events.

Acknowledgements

Thank you to the site co-operators at Toobeah. This project was co-funded by the Queensland Department of Agriculture and Fisheries (DAF) and the Grains Research and Development Corporation, and overseen by the DAF weeds team.

Trial details

Location:	Toobeah
Crop:	Fallow
Soil type:	Grey Vertosol
Trial rainfall:	200 mm

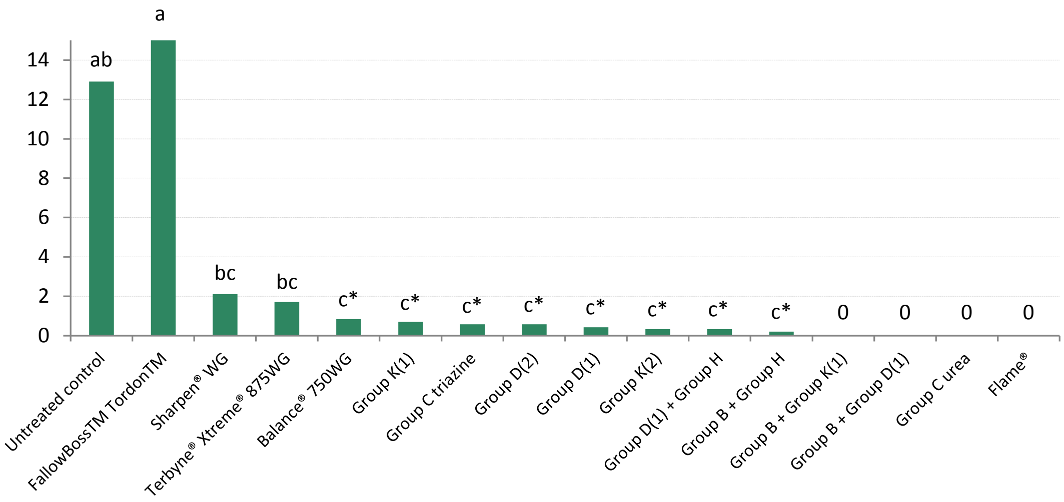

Figure 1. Awnless barnyard grass seedlings established/m², assessed 28 days after herbicide application
Values with similar letters are not significantly different (p 0.05). Treatments with zero in all replicates were removed from the analysis
* = not significantly different to zero (p 0.05)

Awnless barnyard grass: efficacy of residual herbicides—Boomi

Andrew Erbacher
Department of Agriculture and Fisheries

***Research Questions:** How effective are different residual herbicides in controlling awnless barnyard grass* (Echinochloa colona)*, and how does this change over time? What is the impact of residual herbicides on subsequent crop establishment?*

Key findings

1. Group K(1) herbicide has provided very good control of awnless barnyard grass for two months after application.
2. The mixing of two herbicides with different modes-of-action improved the level of control achieved over either of the individual products.

Background

Awnless barnyard grass (ABYG) is an annual weed that is common to summer fallow paddocks in southern Queensland and northern New South Wales. It will germinate and establish in multiple cohorts in a season, but the first germination in spring is typically the largest. These spring germinations are often from storm rain and the weeds then stress quickly as the soil dries; so it can be difficult to control the stressed weeds with translocated systemic herbicides such as glyphosate.

Furthermore, surveys in 2007 identified approximately 100 populations of ABYG with Group M (glyphosate) resistance. To combat this increasing resistance, residual herbicides can be used as part of an integrated weed management (IWM) program to provide a wider range of modes-of-action (MOA) and so reduce the population of weeds that need to be controlled by other tactics (such as crop competition, knock-down herbicides and tillage).

However, there are incomplete efficacy and plant back data on some new and existing residual herbicides that may be suitable for ABYG. Three trials were established on the Western Downs over the 2015-16 summer (nine trials in total) to help increase local data on the efficacy and duration of control provided by these residual herbicides on ABYG and other associated broadleaf and grass weeds. This paper reports one the trials near Boomi in far north New South Wales.

PLEASE NOTE:
Products/combinations in this field experiment were tested FOR RESEARCH PURPOSES ONLY.

Not all products used are registered for the purposes we have tested. Always read the label prior to use and only apply herbicides as approved in the label.

What was done

The trial was established on a heavy Black Alluvial Vertosol, 50 km west of Goondiwindi. The paddock was long-fallowed out of a forage sorghum crop in which a population of sowthistle and awnless barnyard grass had established and set seed. The paddock was cultivated twice, with offsets and speed tillers, prior to the application of a range of herbicide options likely to control both of the dominant weeds in this paddock (Table 1).

The treatments were applied to 3 m x 10 m plots with three replicates on 21 December 2015, using a boom on a quad bike. The 15 herbicide treatments were applied in 100 L/ha of water with an air inducted coarse (C) droplet size.

On 17 March (87 days after application; DAA) soil was collected and placed into cold storage for later use in pot trials to assess biological symbiotic associations (rhizobia and mycorrhiza); reported separately by Nikki Seymour (see page 199).

Approximately two weeks after each rainfall event, established seedlings within fixed quadrats were counted; then sprayed out to prevent double counting and competition effects on later germination events.

Assessments were made on:

- 18 January (28 DAA)
- 15 February (56 DAA)
- 7 April (108 DAA)
- 17 May (148 DAA)

Table 1. Treatments applied

Trt No.	MOA	Product/s	Rate (/ha)
1	-	Untreated control	-
2	B	Flame®	200 mL
3	D	Group D(1)	3.3 L
4	C	Terbyne® Xtreme®	1.2 kg
5	H	Balance® 750WG	100 g
6	K	Group K(1)	2 L
7	B + H	Group B + Group H	200 mL + 100 g
8	B + K	Group B + Group K(1)	200 mL + 2 L
9	B + D	Group B + Group D(1)	200 mL + 3.3 L
10	D + H	Group D(1) + Group H	3.3 L + 100 g
11	C	Group C triazine	2 kg
12	C	Group C Urea	1 kg
13	G	Sharpen® WG	34 g
14	I	FallowBoss™ Tordon™	1 L
15	K	Group K(2)	1 L
16	D	Group D(2)	3 L

Results

Rain (6 mm) fell two days after the treatments were applied, which was sufficient to incorporate the herbicides into the soil but did not produce any germination of weeds. From 4 January, 82 mm of rain fell over three days, resulting in a large initial germination at the site.

On 18 January (28 DAA) the untreated control established 1752 ABYG per square metre (Figure 1). Three of the 15 herbicides applied had populations not significantly different to the untreated control. The best two treatments (signified by the letter 'i') achieved 99.9% control of ABYG, with eight treatments (letters 'e' to 'i') achieving commercially acceptable control of >90% reduction of established weeds. The best two treatments were Group K(1) alone and in combination with Group B. The other individual products that provided acceptable levels of control were Group K(2) and Group C triazine.

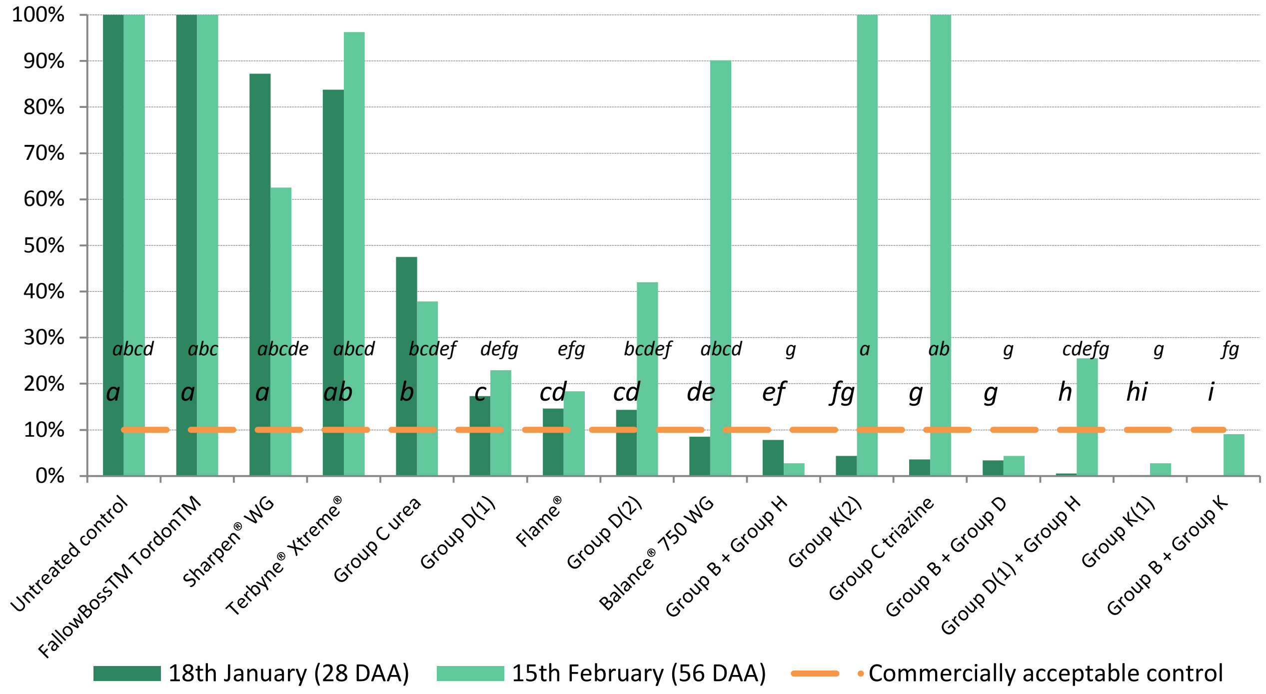

Figure 1. Awnless barnyard grass seedlings established, assessed 28 and 56 days after herbicide application
Data is presented relative to the untreated control. Bars within the same series (colour) with similar letters are not significantly different at the 5% significance level

On 28 January a further 17 mm of rainfall resulted in a smaller second germination event (8 ABYG/m^2 in the untreated control), which was assessed on 15 February (56 DAA) (Figure 1). Four treatments were still providing commercially acceptable control. These were Group K(1) and the three combination treatments that included Group B. Statistically similar results to this 'lead' group were measured for Flame; Group D(1); and the Group D(1) + Group H combination treatment. Group C triazine and Group K(2) performed poorly at this later date.

The knockdown application applied after the January assessment did not kill all of the seedlings in four treatments (those with the significance letter 'a'). It is likely that a competition effect from the persisting weeds may have reduced the number of weeds establishing in these four treatments at the following assessment.

Assessments on 18 January (28 DAA) and 15 February (56 DAA) showed significant differences in established populations of ABYG. Cooler weather and seedbank rundown from the removal of weeds after the early assessments meant later rainfall events didn't establish sufficient ABYG seedlings to measure herbicide effects over a longer period.

Despite evidence of a past sowthistle population in the paddock, only four seedlings established for the life of the trial; so no conclusions were possible for this weed.

Chickpeas were planted on 19 June (183 DAA). No population differences or visual signs of herbicide damage to the crop were evident when assessed four weeks after planting.

Implications for growers

With rainfall shortly after application, Group K(1) and Group K(2) provided very good short term control of awnless barnyard grass. While Group K(1) has sustained this control for two months post application, the control achieved by Group K(2) was much shorter.

The mixing of two herbicides with different modes-of-action improved the level of control achieved by either of the individual products. While Flame® struggled to produce commercially acceptable results on its own in this trial, it was very effective as a low cost mixing partner.

This trial was very effective in demonstrating the principle of seedbank rundown. In a short period of time, we have been able to reduce the weed potential of the site from 1 plant/cm^2 to scattered plants across the paddock, by intensively managing the patch of weeds and not allowing any plants set seed.

Acknowledgements

Thank you to the site co-operators at Boomi. This project was co-funded by the Queensland Department of Agriculture and Fisheries (DAF) and the Grains Research and Development Corporation, and overseen by the DAF weeds team.

Trial details

Location:	Boomi
Crop:	Fallow
Soil type:	Black Vertosol
Trial rainfall:	160 mm

Awnless barnyard grass (*Echinochloa colona*)

Impacts of residual herbicide on soil biological function

Nikki Seymour
Department of Agriculture and Fisheries

RESEARCH QUESTION: *What are the impacts of residual herbicides applied over a summer fallow on subsequent biological symbiotic associations (rhizobia and mycorrhiza) in winter crops (chickpea and wheat) and biological components (nematode communities, microbial activity) of the soil?*

Key findings

1. Residual herbicides can impact on microbial function particularly if sensitive plants are grown in treated soil before or close to the fallow time recommended before planting.
2. Shoot and root growth as well as number and dry weight of the nodules of the chickpea plants grown in the soils treated with some herbicides, were significantly reduced. Nitrogen fixation would be significantly reduced as a result.
3. Mycorrhizal colonisation of wheat does not appear to be negatively impacted by herbicide residues in soils.

Background

Field trials conducted by the regional agronomy team and the weeds team within the Sustainable Farming Systems group of Crop and Food Science, Queensland Department of Agriculture and Fisheries, have given an opportunity to viably assess the impact of some residual herbicides on certain crop associated soil biological functions and components.

With the increase in glyphosate resistance and difficult to control weeds in the northern region, alternative weed management tactics are required. One such alternative is residual herbicides. Residual herbicides can provide medium to long-term control of weeds in fallow and crop by controlling several flushes of emergence. However the efficacy of residual herbicides can be affected by the environment (soil type, rain fall, temperature). Therefore, it is necessary to gather local efficacy and persistence data across a range of environments and seasons. Persistence of residual herbicides can then have flow-on effects on the biological components of soils either directly or indirectly (through reduced plant and root growth).

PLEASE NOTE:
Products/combinations in this field experiment were tested FOR RESEARCH PURPOSES ONLY.

Not all products used are registered for the purposes we have tested. Always read the label prior to use and only apply herbicides as approved in the label.

What was done

Residual herbicide trials were conducted across Queensland over the summer of 2015/16. Three sites operated out of each of Emerald, Goondiwindi and Toowoomba (nine sites in total) were established to investigate the efficacy of residual herbicides on sowthistle and key summer grasses (awnless barnyard grass, feathertop Rhodes grass and liverseed grass). Bioassays using soil samples collected 90 days post-spraying were then conducted to study the impact on soil biota such as mycorrhizal fungi and beneficial nematodes as soil health indicators and on key biological associations such as nodulation with N fixing bacteria.

Site

Each field trial was established at a site/s where there was an expected uniform density of a minimum 30-50 plants/m^2 for each flush of emergence (often difficult to predict). This was to ensure there would be enough target weed species to distinguish between treatments either alone or in mixture.

Experimental design

- Randomised block
- 3 replications x 16 herbicide treatments
- Pot size: 8m x 2m

Application of treatments

To start with a weed-free trial site, weeds were initially sprayed out with a non-residual knockdown herbicide (eg. glyphosate or paraquat). Herbicide treatments (Table 1) were applied at a spray volume of 100 L/ha using 110 015 flat fan nozzles on a shrouded boom. At most sites, herbicides were incorporated by rain shortly after application, however at two sites forecast rain did not eventuate, so overhead irrigation was used to achieve this.

Table 1. Treatments (note not all treatments applied at all sites)

Trt No.	MOA	Product/s	Rate (/ha)
1	-	Untreated control	-
2	B	Flame®	200 mL
3	D	Group D(1)	3.3 L
4	C	Terbyne® Xtreme®	1.4 kg
5	H	Balance® 750WG	100 g
6	K	Group K(1)	2 L
7	B + H	Group B + Group H	200 mL + 100 g
8	B + K	Group B + Group K	200 mL + 2 L
9	B + D	Group B + Group D	200 mL + 3.3 L
10	D + H	Group D + Group H	3.3 L + 100 g
11	C	Group C Triazine	1 kg
12	C	Group C Urea	1 kg
13	G	Sharpen® WG	34 g
14	I	FallowBoss™ Tordon™	1 L
15	K	Goup K(2)	1 L
16	D	Group D(2)	3 L

Bioassays

A minimum of 5 kg of soil to a depth of 10 cm from each plot was collected 90 days post application. Soil from each treatment at each site was potted into 3 x 1.5 L pots and planted to either uninoculated chickpea, inoculated chickpea (with rhizobia Group N strain CC1192) or to wheat. Soil was also collected for a nematode community analysis at time of sampling and soil physical characteristics. Whilst an analysis of the level of herbicide residue at this time would also be of interest, it is cost prohibitive to do all samples and so specific plots/treatments from the 2016/7 trials will be analysed immediately after sampling.

Plants were grown for eight weeks at which time top and root growth was assessed and nodulation due to rhizobia was scored for each of the chickpea treatments. Wheat roots were subsampled for mycorrhizal colonisation assessments.

Results

Whilst analyses are still underway, preliminary results are indicating that residual effects of Flame® (Trt 2), Group B + H (Trt 7), Group C Urea (Trt 12) and of FallowBossTM TordonTM (Trt 14) have all had negative impacts on nodulation and in some cases growth of the plant. Reductions of varying extents in nodulation and plant growth were observed across all sites, an example of which can be seen at the Toobeah site in southern Queensland (Figures 1 and 2).

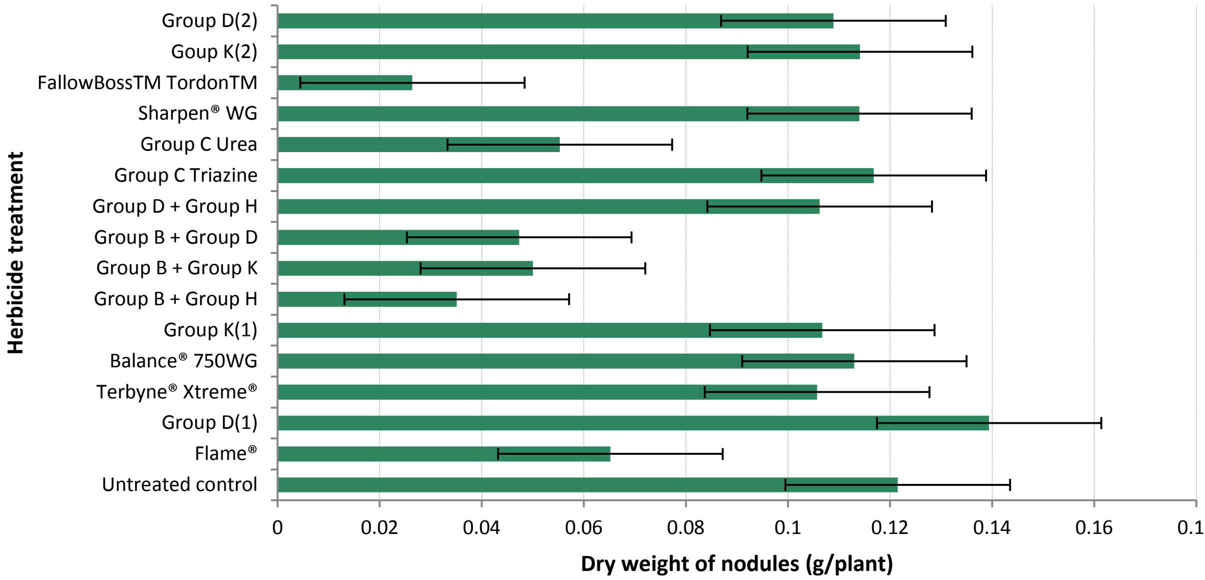

Figure 1. The dry weight of nodules on 8 week-old chickpea plants grown in pots of a Vertosol that was collected from a paddock at Toobeah 90 days post application of various residual herbicides

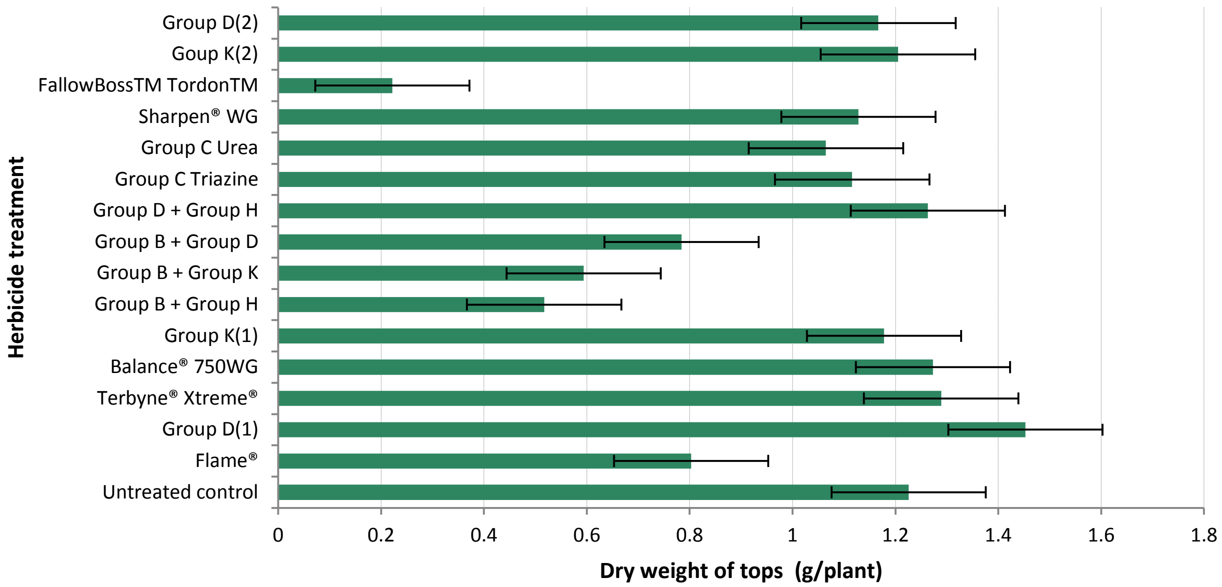

Figure 2. The dry weight of shoots of 8 week-old chickpea plants grown in pots of a Vertosol that was collected from a paddock at Toobeah 90 days post application of various residual herbicides

These effects are not totally surprising as these active ingredients are all listed as being slowly degraded by microbes with average degradation rates of 89 (Group C Urea) to 232 (Flame) days (Congreve and Cameron 2014[1]) and with plant back periods for chickpea of 3–4 months. Extent of incorporation following application (for example by rain) can greatly influence degradation times as can soil temperature and moisture. We sampled at 90 days post application so given the dry season over the summer, these slower to degrade herbicides are obviously still persisting and having negative impacts on plant growth and nodulation of the sensitive species chickpea.

Mycorrhizal colonisation of wheat roots completed for the Toobeah site have shown no impacts of the herbicides on %AMF colonisation with levels consistently around 50-60% (considered a high level of colonisation in wheat). Nematode community analyses are not complete yet.

Implications for growers

Growers need to carefully adhere to recommended plant back periods for sensitive crops and be especially careful if the seasons have not lent themselves to complete herbicide breakdown. Not only will growth of the crops be reduced but damage due to the presence of residual herbicide in the soil will also lead to reduced nodule size and numberin a following chickpea crop. This impact on nodulation will reduce nitrogen fixation capacity, leading to potential N deficiency in the pulse crop with carry over impacts on the following cereal crop.

Acknowledgements

Thanks to growers who allowed these trials to be conducted on their properties and for the technical assistance from Department of Agriculture and Fisheries staff.

Trial details

Locations:	Goondiwindi (3), Emerald (3), Warwick (1) and Kingaroy (1)
Crop:	Fallow, followed by chickpea or wheat in bioassays (glasshouse pot trial)
Soil type:	Vertosols, Alfisol

Chickpea and wheat grown in soils sampled from a field trial comparing residual herbicides

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[1] Congreve, M. and Cameron, J. 2015, Soil behaviour of pre-emergent herbicides in Australian farming systems, a reference manual for agronomic advisors. Grains Research and Development Corporation.

Pathology research

In 2016 the regional agronomy team continued research into mungbean and winter cereal pathology. The key areas of focus in 2016 were the control of powdery mildew in mungbean crops and assessing the yield impact of crown rot across a range of wheat and barley varieties.

Managing disease in mungbeans remains one of the major production challenges facing growers. Powdery mildew (*Podosphaera xanthii*) is found wherever the crop is grown and can cause significant yield loss, particularly in late planted crops when weather conditions are more favourable to disease development. Although newer varieties have greater disease resistance, most are still rated susceptible or very susceptible. Only Green Diamond$^{\phi}$ and Jade-AU$^{\phi}$ have a slightly higher rating of moderately susceptible to powdery mildew.

Apart from plant resistance, foliar fungicides are the only viable option available for the management of powdery mildew in mungbeans. Past trials indicate that the best level of control can be achieved when the first fungicide spray is applied at the first sign of powdery mildew (normally found on the lower leaves of a vegetative crop), followed by a second spray two weeks later. Further research was required to confirm the most efficacious fungicide and timing of the first spray and to quantify yield benefits. In 2015-16 trials were established at Emerald, Kingaroy and Warwick to build on past research work and to refine powdery mildew control recommendations.

Far left: Spraying fungicide treatment in a powdery mildew trial at Kingaroy

Left: Treated (back) and untreated (front) mungbeans showing differences in the development of powdery mildew

Crown rot screening trials were conducted at Meandarra and Westmar in conjunction with trials conducted by the New South Wales Department of Primary Industries. The trials were designed to compare the relative yield loss of a range of bread wheat, barley and durum varieties in the presence or absence of crown rot and identify any possible indication of resistance during the process of screening the range of winter cereals.

Depending on location, crop and variety, yield loss varied greatly, with all three crops showing significant yield losses on susceptible varieties. Durum wheats appeared to be the most susceptible with significant yield loss, while the barley varieties showed the least yield losses across all crops. However these yield losses were still economically significant and highlight the affect crown rot could be having to winter grain production in Queensland and the need to be vigilant in managing the pathogen to minimise yield loss.

Right: Crown rot symptoms

Mungbean: powdery mildew control

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RESEARCH QUESTIONS: *Determine the most efficacious timing of tebuconazole (as Folicur® 430 SC) fungicide to manage powdery mildew* (Podosphaera fusca (syn. Podosphaera xanthii)) *in mungbean cv. Jade-AU$^{\Phi}$. Quantify yield differences due to fungicide application.*

Key findings

1. The fungicide tebuconazole (as Folicur® 430 SC) is an effective fungicide for the management of powdery mildew on mungbean crops.
2. Controlling powdery mildew in mungbeans using tebuconazole can be a cost effective management practice.

Background

Powdery mildew in mungbeans is caused by the fungus *Podosphaera xanthii* and is found wherever the crop is grown. The fungus requires a living host and is unable to survive in plant residues. Although there are several confirmed hosts that can carry over the disease from one season to another, infection can also originate from spores traveling long distances given the right conditions. In Queensland and New South Wales, the disease is favoured by moderate temperatures (22-26°C) with high relative humidity and tends to appear in late-planted crops maturing into cooler conditions.

Infected plants have a greyish-white powdery growth on the surface of leaves, stems and pods (Image 1). It is first evident as small circular spots on the lower leaves, which then rapidly cover the entire leaf and then spread to the younger leaves higher up the plant (Image 2). Infection can appear at any growth stage, depending on weather conditions.

Yield losses due to powdery mildew vary from year to year but can be significant if development occurs before or at flowering. Late infections during pod fill can cause leaf drop but do not appear to seriously affect yield. Yield losses most commonly range between 10 and 15% however can be as high as 46% depending on the variety, growth stage at infection, and rate of disease development.

Plant resistance and foliar fungicides are the only two viable options available for the management of powdery mildew in mungbeans. Most varieties are rated susceptible, except for Green Diamond$^{\Phi}$ and Jade-AU$^{\Phi}$, which have a slightly higher rating of moderately susceptible to powdery mildew.

Even though there are several formulations of sulfur either registered or under permit for the management of powdery mildew in mungbeans, the systemic fungicide tebuconazole currently under APVMA permit and sold as Folicur® 430 SC or Hornet® 500SC have better efficacy. Past

Image 1. Severe powdery mildew in mungbeans (Hermitage Research Station)

Image 2. Early establishment of powdery mildew in mungbeans

trials conducted over several seasons have indicated that control will be achieved if the first tebuconazole spray is applied at the first sign of powdery mildew on the lower leaves of a vegetative crop, followed by a second spray two weeks later. However, further research was required to establish the most efficacious timing of the fungicide, in particular the timing of the first spray and to quantify yield benefits.

What was done

Trials were established at three sites; Emerald (Queensland Agricultural Training College - QATC), Warwick (Hermitage Research Station - HRS) and Kingaroy (Kingaroy Research Facility - KRF). Tebuconazole was used under the Australian Pesticides and Veterinary Medicines Authority (APVMA) permit number PER13979.

The trials consisted of a randomised block design, of seven treatments each with four replications. Each plot had 4 x 12 m planted rows with a row spacing of 0.75 m at QATC and HRS and a row spacing of 0.9 m at KRF. Plots were planted with Jade-AU$^{\Phi}$, the variety with the highest level of resistance and currently considered the industry standard. Each plot was separated by two rows of mungbean (variety Berken). Berken is an old mungbean variety and highly susceptible to powdery mildew (rated: very susceptible), hence it was used in this situation to promote the development of the disease in the trial.

Folicur® 430 SC (active ingredient tebuconazole 430 g/L) was applied at 145 mL/ha using a pressurised hand-held 2 m boom sprayer delivering 134 L/ha at five km/hr (Table 1).

The first sign of powdery mildew and subsequent spraying (T5 and T6) occurred at:

- Kingaroy: 9 March 2016 (19 days after emergence (DAE))
- Hermitage: 8 March 2016 (25 DAE)
- Emerald: 17 March 2016 (29 DAE)

Treatment plots were regularly monitored and assessed for powdery mildew. Infection levels were rated and recorded (Table 2).

Table 2. Powdery mildew infection severity rating (ISR) scale

ISR	Infection description
1	No powdery mildew colonies observed on any plants
2	Small colonies in lower 1/3 of canopy, up to 75% of plants affected
3	Colonies in lower 1/2 of canopy, >75% of plants affected
4	Colonies in lower 2/3 of canopy, up to 75% of plants affected
5	Colonies in lower 2/3 of canopy, >75% of plant affected
6	Colonies in lower 2/3 of canopy, 100% plants affected
7	Colonies in lower 2/3 of canopy of 100% of plants, some plants with colonies in top 1/3 of canopy
8	Colonies to top of plant with >75% of plants affected
9	Colonies to top of plant with 100% of plants affected and heavy leaf drop

Table 1. Treatment descriptions

Treatment	Description	Total sprays
T1	Control, no fungicide application	0
T2	Spray 1: applied 28 days (Emerald and Hermitage) or 32 days (Kingaroy) after emergence	1
T3	Spray 1: applied 28 days (Emerald and Hermitage) or 32 days (Kingaroy) after emergence Spray 2: applied 14 ± 2 days after spray 1	2
T4	Spray 1: applied 28 days (Emerald and Hermitage) or 32 days (Kingaroy) after emergence Spray 2: applied 14 ± 2 days after spray 1 Spray 3: applied 14 ± 2 days after spray 2	3
T5	Spray 1: applied at the first sign of powdery mildew	1
T6	Spray 1: applied at the first sign of powdery mildew Spray 2: applied 14 ± 2 days after spray 1	2
T7	Spray 1: applied when powdery mildew was 1/3 up the canopy Spray 2: applied 14 ± 2 days after spray 1	2

Results

Emerald

The trial was planted on 12 February 2016 and emerged on 18 February 2016. Plots were rated on a whole plot basis on 7 April 2016 (49 DAE) and 22 April 2016 (64 DAE).

Powdery mildew developed slowly in the trial and never reached severe levels. The control (untreated) plots had a mean powdery mildew severity rating of 2.8, 20 DAE and a rating of 4.5, 15 days later (35 DAE). The final mean powdery mildew severity rating (64 DAE) for the control plots remained at 4.5. There were no statistically significant differences in either mean powdery mildew severity ratings or grain yield between any treatments (Table 3) reflecting the influence high temperatures and associated low humidity has on the build-up of infection. Also, individual plants were small compared to those at the other KRF and HRS trial sites. An open canopy allowed significant air movement across the trial which also helped limit powdery mildew build-up.

Table 3. Grain yield and disease severity at Emerald 2016

	Final severity rating	Grain yield (t/ha)	Percentage yield increase[#]
T5	3.3	0.93	15.0
T2	3.5	0.87	8.1
T4	2.8	0.85	5.3
T3	2.5	0.83	3.4
T6	2.8	0.81	0.5
T1	4.5	0.81	0
T7	4.5	0.79	-2.7

[#] Yield increase = (mean yield sprayed treatment – mean yield control plot) x 100 / mean yield of control plot. Severity ratings and table by Sue Thompson, USQ

Due to the relatively low levels of powdery mildew in the trial and high variability between replicates no significant differences in either grain yield or powdery mildew severity between any of the treatments were detected. Low levels of powdery mildew were a function of high temperatures during the trial. The mean daily temperature between the initial appearance of the disease, 29 DAE and the final severity rate at 65 DAE was 26°C, whereas the corresponding temperature for the trial at Hermitage was 21.7°C; conducive to extremely high levels of disease.

Kingaroy

The trial was planted on 11 February 2016, emerged on 19 February 2016 and harvested on 10 May 2016 (81 DAE). Plots were rated on a whole plot basis on 10 March 2016 (20 DAE), 24 March 2016 (34 DAE), 5 April 2016 (49 DAE) and 19 April 2016 (60 DAE).

Powdery mildew was first observed in the trial 19 DAE and developed rapidly reaching a severity rating of 8.3 in the untreated plots (T1) 60 DAE. Spray treatments T5 and T6 which required the first spray to be applied at first sign of powdery mildew held the disease at the same level for approximately 14 days. The disease then developed rapidly in T6 (received only one spray) and reached a severity rating of 7.8, 60 DAE. Treatment 6 received a second spray 14 days after its first spray, resulting in only a slight increase in disease severity over the following 14 days after which the disease developed rapidly to reach a severity score of 6.5, 60 DAE (Figure 1).

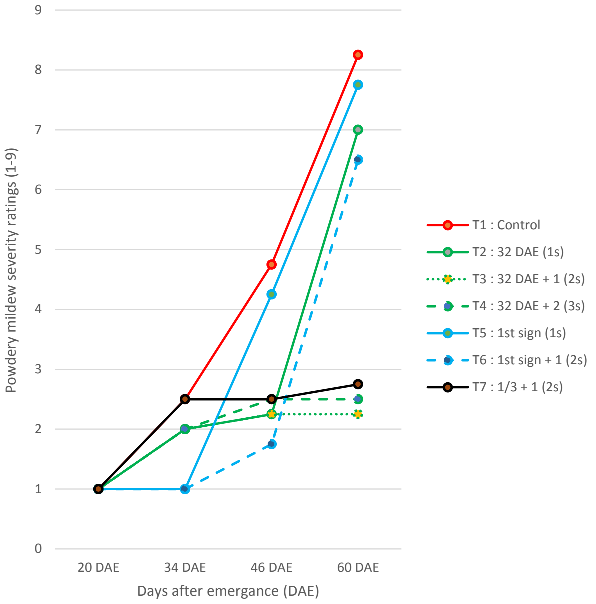

Figure 1. Development of powdery mildew in mungbeans at Kingaroy

Treatments 2, 3 and 4 received their first spray 32 DAE. Disease development was held at similar severity levels for the next 14 days. After this point the disease developed rapidly in T2 (which received only one spray) and reached a severity score of 7 at 60 DAE. Disease severity for T3 and T4 (both receiving a second spray and T4 a third spray) did not develop further. At 60 DAE the disease severity of T3 was 2.3 and 2.5 for T4. Treatment 7 receiving its first spray 49 DAE and a second spray 14 days later did not develop further disease from its initial level. At 60 DAE T7 had a disease severity rating of 2.8 (Figure 1).

At the final rating (60 DAE) T3, T4 and T7 were the most efficacious treatments, significantly better ($P \leq 0.05$) than all the other treatments. Treatments two and six were significantly better than T1 and T5, with no difference between T1 and T5 (Table 4).

Table 4. Grain yield and final powdery mildew severity rating at Kingaroy Research Facility 2016

	Final severity rating	Grain yield (t/ha)	Percentage yield increase#
T3	2.3 a	0.78	32.7
T2	7.0 b	0.76	30.6
T7	2.8 a	0.70	19.2
T6	6.5 b	0.69	18.2
T5	7.8 c	0.67	14.5
T4	2.5 a	0.64	9.7
T1	8.3 c	0.59	0

#Yield increase = (mean yield sprayed treatment – mean yield control plot) x 100 / mean yield of control plot. Severity ratings and table by Sue Thompson USQ

The trial suffered significantly from a bean fly (*Ophiomyia phaseoli*) infestation early through the seedling growth stage resulting in patchy, uneven plant stands across the trial. This had a direct impact on grain yields and resulted in no significant differences ($P \leq 0.05$) in grain yields between any of the treatments. There was no statistical correlation between the final severity disease rating and yield across the trial. However, a trend is apparent indicating that yield was increased with the application of fungicide.

The application of Folicur® 430 SC 32 days after emergence, followed up with one or two applications 14 days apart has provided significant control of powdery mildew with no impact on yield.

Hermitage

The trial was planted on 3 February, emerged on 12 February and was harvested on 17 May 2016, 76 DAE. Plots were rated on a whole plot basis on 7 March 2016 (24 DAE), 21 March 2016 (38 DAE), 31 March 2016 (48 DAE) and 15 April 2016 (64 DAE).

Powdery mildew was first observed in the trial 25 DAE and developed rapidly, reaching a severity rating of 8.0 in the nil treatment (T1) in the final rating (64 DAE).

Spray treatments T5 and T6 which required the first spray to be applied at the first sign of powdery mildew held the disease at the same levels for approximately 14 days. The disease then developed in both T5 (one spray only) and T6 (two sprays) at an increasing rate reaching a severity rating of 7.5 for T5 and 6.5 for T6 at 64 DAE. (Figure 2). There appeared to be no difference between T5 (one spray) and T6 (two sprays).

Treatments T2, T3, T4 and T7 received the first spray 34 DAE. Disease development was held but at slightly higher levels for the next 10 days. Disease then developed rapidly in T2 (one spray) and reached a severity score 6.3 at 64 DAE. Disease development for T3 and T7 (both receiving a second spray) was significantly restricted, reaching severity levels of 4.5 for T7 and 4.0 for T3 at 64 DAE. Disease in T4 (three sprays) did not develop any further and had a severity rating of 2.3 at 64 DAE (Figure 2).

At the final rating (64 DAE) T4 was the most efficacious treatment, significantly better ($P \leq 0.05$) than all other treatments. Although the disease development and severity of T3 and T7 were significantly worse than T4 they were significantly better than the other treatments. Treatment two and six were significantly worse than T3 and T5, with no difference between T1 (untreated) and T5 which both showed the highest levels of infection (Figure 2).

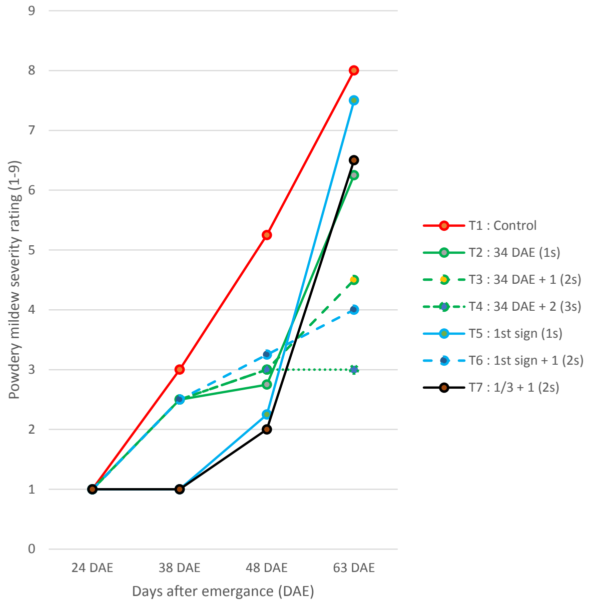

Figure 2. Development of mungbean powdery mildew at Hermitage

All treatments produced significantly greater grain yields than the control (T1), with increases ranging from 17.9% to 30.4%. Treatments which received two or more sprays (T3, T4, T6, T7) produced significantly more yield ($P \leq 0.05$) than treatments which received only one spray (T2 and T5) (Table 5).

Table 5: Final powdery mildew severity and grain yields at Hermitage

	Final severity (1-9)	Grain yield (t/ha)	Percentage yield increase#
T3	4.0 b	2.06 a	30.4
T7	4.5 b	2.03 a	28.8
T6	6.5 c	2.03 a	28.7
T4	2.3 a	2.01 a	27.6
T2	6.3 c	1.93 d	22.6
T5	7.5 d	1.86 c	17.9
T1	8.0 d	1.58 d	0

#Yield increase = (mean yield sprayed treatment – mean yield control plot) x 100 / mean yield of control plot. Severity ratings and table by Sue Thompson USQ

The application of Folicur® 430 SC 34 DAE, followed up with one or two more applications 14 days apart has provided significant control of powdery mildew and higher yields. The application of only one fungicide spray provided some control and was significantly better than the nil fungicide treatment (T1).

Economics of Folicur® application timings

Fungicide treatments provided economic benefits irrespective of time of application at both Hermitage and Kingaroy. Using a mungbean price of $1000/t these yield improvements cover the respective treatment costs (Table 6). Even at $600/t these treatments would have all generated positive returns.

Treatments (T3, T4, T6 and T7), which received two fungicide applications consistently outperformed treatments that only received one fungicide application (T2 and T5). However a third application did not appear to offer any additional benefit over the initial two. The highest returning treatment across both sites was T3, with the first fungicide application occurring four weeks after emergence followed up with a second spray two weeks later.

Implications for growers

Environmental conditions directly influence the establishment and development of powdery mildew in mungbean crops and need to be considered when developing a disease control and management program. This was demonstrated across these three trials. Under hot conditions (as experienced in Emerald) the disease did not reach severe levels of infection and as a result no significant differences in either powdery mildew severity or grain yield were measured between treatments. Under these conditions, implementation of control measures is probably not warranted unless the environmental conditions change. In comparison, under cooler conditions (as experienced at Hermitage), the disease reached severe levels and resulted in statistically significant differences between treatments in yield and disease severity rating. Under these conditions, control measures need to be given significant consideration and carefully implemented to optimise results.

Table 6: Cost benefit analysis of average yields for pathology trials at Hermitage and Kingaroy

		Return on investment for fungicide treatments			
Potential sale price:		*$1000/tonne*		*$600/tonne*	
Treatment	Cost	Hermitage	Kingaroy	Hermitage	Kingaroy
Control (T1)	$0.00	$0.00	$0.00	$0.00	$0.00
T2	$5.83	$356.40	$322.30	$213.84	$193.38
T3	$11.66	$479.44	$344.50	$287.66	$206.70
T4	$17.48	$385.96	$120.96	$231.57	$72.58
T5	$5.83	$282.63	$152.73	$169.58	$91.64
T6	$11.66	$452.24	$191.91	$271.34	$115.14
T7	$11.66	$411.57	$202.11	$246.94	$121.27

The fungicide tebuconazole has been shown to be an effective fungicide for the management of powdery mildew on mungbean crops. The efficacy of different spray schedules varies from year to year depending on the environmental conditions. These conditions influence the time at which the disease first establishes itself and the subsequent rate of development in the crop. Trial results indicate that greatest efficacy was achieved when the first fungicide application was applied four to five weeks after emergence followed by one or two repeated application 14 days apart. Applying a fungicide treatment at the first sign can also be effective but one or two follow up applications may be necessary to provide the best control.

Mungbean powdery mildew will rapidly colonise a crop if conditions are favourable and can cause significant yield losses. When making a decision on controlling powdery mildew in mungbeans there are a number of key considerations. These include having an understanding of the biology of the pathogen, closely monitoring the crop for first incidence, the crop growth stage, and environmental conditions.

Acknowledgements

We would like to acknowledge the University of Southern Queensland as lead agency and the Grains Research and Development Corporation funding.

Trial details

Location:	Queensland Agricultural Training College , Emerald (QATC), Kingaroy Research Facility (KRF), Hermitage Research Station (HRS)
Crop:	Jade-AU⦸ mungbeans
Soil type:	Cracking Black/Grey Vertosol (QATC), Cracking Black Vertosol (HRS), Red Ferrosol (KRF)
In-crop rainfall:	All crops were irrigated
Fertiliser:	50 kg/ha Granulock Z®

Powdery mildew levels in treated (back) and untreated (front) mungbean plots at Hermitage Research Station 2016

Wheat and barley: regional crown rot management—Westmar

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[2]NSW Department of Primary Industries

***Research Questions:** What is the relative yield loss of a range of bread wheat, barley and durum varieties in the presence or absence of crown rot? Is this an indication of resistance?*

Key findings

1. The presence or absence of crown rot has an extreme impact on the yield performance of all winter cereal varieties tested. Yield loss in the presence of crown rot infection ranged from 16-39% in the bread wheats and 17-33% in the barley varieties.
2. The three durum entries preformed very poorly losing between 45-52% of their yield.
3. Resistance ratings are a poor indicator of potential yield loss in an individual trial as the results are quite variable, even within resistance rating groups. The moderately susceptible–susceptible (MSS) varieties Suntop⏀, Sunmate⏀, LongReach Flanker⏀ and LongReach Lancer⏀ lost between 20-33%. The moderately susceptible (MS) rated varieties were more consistent LongReach Gauntlet⏀, Sunguard⏀ and Mitch⏀ each lost 16% of their yield while LongReach Spitfire⏀ was an outlier and lost 35%, a poorer result than the MSS rated varieties.
4. The new varieties both performed quite poorly. LongReach Reliant⏀ lost 39% of its yield (equivalent to EGA Gregory⏀), while Coolah⏀ lost 33% of its yield (equivalent to LongReach Flanker⏀).

Background

Crown rot (CR) caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to the production of winter cereals in Queensland and northern New South Wales. Cereal varieties differ in their resistance to crown rot which can have a significant impact on their relative yield in the presence of this disease. The Westmar trial was one of 12 conducted by New South Wales Department of Primary Industries in 2016 across central/northern New South Wales extending into southern Queensland to examine the impact of crown rot on the yield of four barley, three durum and 13 bread wheat varieties or experimental lines.

What was done?

The trial consisted of:

- Four barley varieties (Compass⏀, Commander⏀, La Trobe⏀ and Spartacus CL⏀)
- Two durum varieties (Jandaroi⏀ and DBA Lillaroi⏀) and one experimental line (190873)
- Ten commercial bread wheat varieties: EGA Gregory⏀, LongReach Flanker⏀, Sunmate⏀, LongReach Gauntlet⏀, LongReach Lancer⏀, LongReach Spitfire⏀, Beckom⏀, Mitch⏀, Suntop⏀ and Sunguard⏀ (listed in order of increasing resistance to crown rot), two new varieties LongReach Reliant⏀, Coolah⏀ and one experimental line (LPB12-0494).

For each entry there were three replicates of both added and no added crown rot. Crown rot was added at sowing using sterilised durum grain colonised by at least five different isolates of *Fp*.

Yield at 11% moisture and grain protein were measured to determine differences between inoculated plots and non-inoculated plots for each variety.

Results

In all entries, the application of crown rot inoculum significantly decreased yield. Yield loss ranged from 16% for Mitch⏀, LongReach Gauntlet⏀ and Sunguard⏀ to 52% for Jandaroi⏀. This equates to a loss of between 0.63 and

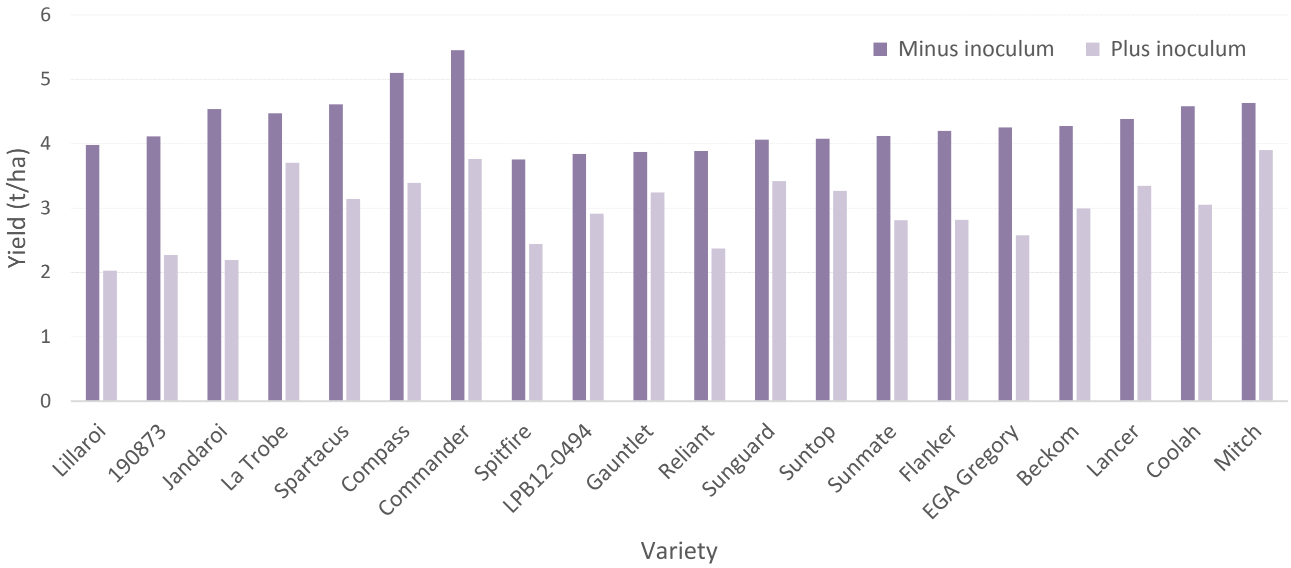

Figure 1. Yield comparisons for all varieties with and without crown rot inoculum added (lsd at P=0.05)

2.34 t/ha (Figure 1). Almost invariably the yield of the plots left untreated yielded higher than all of the plots with inoculum added. The only exceptions were Mitch⏀ and Commander⏀. The new varieties, LongReach Reliant⏀ and Coolah⏀ performed quite poorly; in the presence of crown rot, the yield of these two varieties was reduced to 61% and 67% of the untreated yield respectively. This equates to a susceptible (S) or MSS rating when compared to the yield loss for EGA Gregory⏀ and LongReach Flanker⏀.

The durum varieties all performed very poorly. The yield of Jandaroi⏀ was reduced by 52%, the yield of DBA Lillaroi⏀ was reduced by 49% and the yield of the experimental line 190873 was reduced by 45%.

The durum wheats were the only group that recorded consistent significant results for grain protein. For each of the varieties adding crown rot resulted in an increase in grain protein by approximately 1% (Figure 2). La Trobe⏀ was the only barley variety to record a significant change. In this instance the grain protein was reduced by 1.0%. For the bread wheat varieties there were no significant differences in grain protein with the addition of crown rot.

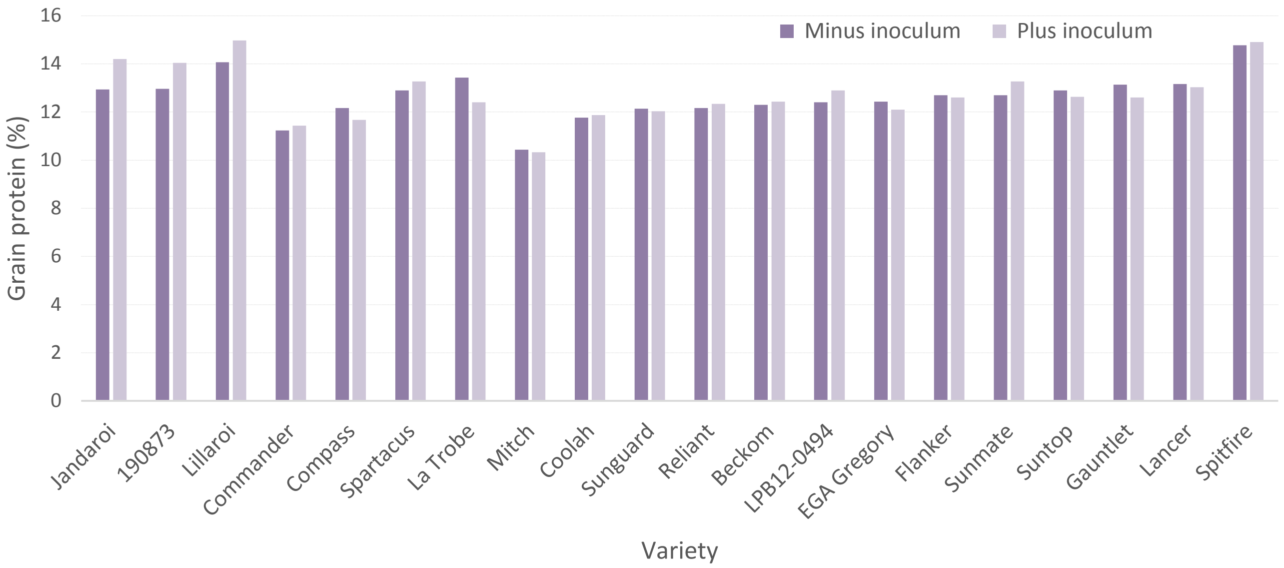

Figure 2. Grain protein comparisons for all varieties with and without crown rot inoculum added (lsd at P=0.05)

Implications for growers

Growers need to be aware of the deleterious impact of crown rot on the yield of their winter cereals. In all cases the addition of *Fp* inoculum resulted in a significant yield loss. The more susceptible varieties, durum wheats, suffered yield losses of 45-52%, while the more tolerant barley varieties lost between 17% and 33% of their yield. The range of yield loss from the bread wheat varieties was from 39% for EGA Gregoryᶲ (a susceptible variety) to 16% for Mitchᶲ, Sunguardᶲ and LongReach Gauntletᶲ (all moderately susceptible varieties). It is interesting to note that the only other MS rated variety, LongReach Spitfireᶲ lost 35% of its yield. This is comparable with the yield loss of the susceptible varieties (e.g. EGA Gregoryᶲ).

Acknowledgements

This trial work was funded by the Grains Research and Development Corporation through the New South Wales Department of Primary Industries and the Department of Agriculture and Fisheries under project DAN00175.

Trial details

Location:	Westmar
Crop:	Wheat, barley and durum
Soil type:	Vertosol
In-crop rainfall:	288.5 mm
Sowing date:	13 June 2016
Fertiliser at planting:	120 kg/ha urea 40 kg/ha Granulock® 12Z (Zn 2%)
Harvest date:	8 November 2016

Crown rot trial site at Westmar

Wheat and barley: regional crown rot management—Meandarra

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[2]NSW Department of Primary Industries

***Research Questions:** What is the relative yield loss of a range of bread wheat, barley and durum varieties in the presence or absence of crown rot? Is this an indication of resistance?*

Key findings

1. The application of crown rot had a significant detrimental impact on the yield of all barley and wheat varieties (except Suntop$^{\phi}$). Suntop$^{\phi}$ experienced the smallest yield reduction in the presence of crown rot (11%). Coolah$^{\phi}$experienced the highest yield loss (42%).
2. The four barley varieties were the least impacted by crown rot infection with yield loss ranging from 12-23%.
3. Yield loss in the presence of crown rot infection in this experiment did not match the rating of varieties for resistance. EGA Gregory$^{\phi}$, a susceptible variety, performed in accordance with its rating (36% yield loss). LongReach Lancer$^{\phi}$ and LongReach Flanker$^{\phi}$ both recorded similar yield loss to EGA Gregory$^{\phi}$ despite having a higher resistance rating (MSS).

Background

Crown rot (CR), caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to the production of winter cereals in Queensland and northern New South Wales. Cereal varieties differ in their resistance to crown rot which can have a significant impact on their relative yield in the presence of this disease. The Meandarra trial was one of 12 conducted by New South Wales Department of Primary Industries in 2016 across central/northern New South Wales extending into southern Queensland to examine the impact of crown rot on the yield of four barley, three durum and 13 bread wheat varieties or experimental lines.

What was done?

The trial consisted of:

- Four barley varieties (Compass$^{\phi}$, Commander$^{\phi}$, La Trobe$^{\phi}$ and Spartacus CL$^{\phi}$)
- Two durum varieties (Jandaroi$^{\phi}$ and DBA Lillaroi$^{\phi}$) and one experimental line (190873)
- Ten commercial bread wheat varieties: EGA Gregory$^{\phi}$, LongReach Flanker$^{\phi}$, Sunmate$^{\phi}$, LongReach Gauntlet$^{\phi}$, LongReach Lancer$^{\phi}$, LongReach Spitfire$^{\phi}$, Beckom$^{\phi}$, Mitch$^{\phi}$, Suntop$^{\phi}$ and Sunguard$^{\phi}$ (listed in order of increasing resistance to crown rot), two new varieties LongReach Reliant$^{\phi}$, Coolah$^{\phi}$ and one experimental line (LPB12-0494).

For each entry there were three replicates of both added and no added crown rot. Crown rot was added at sowing using sterilised durum grain colonised by at least five different isolates of *Fp*.

Yield at 11% moisture and grain protein were measured to determine differences between inoculated plots and non-inoculated plots for each variety.

Results

In all cases, except Suntop$^{\phi}$, the application of crown rot inoculum significantly decreased yield. Yield loss ranged from 11% for Suntop$^{\phi}$ (not significant) to 42% for Coolah$^{\phi}$. This equates to a loss of between 0.49 t/ha and 2.17 t/ha (Figure 1). Almost invariably the yield

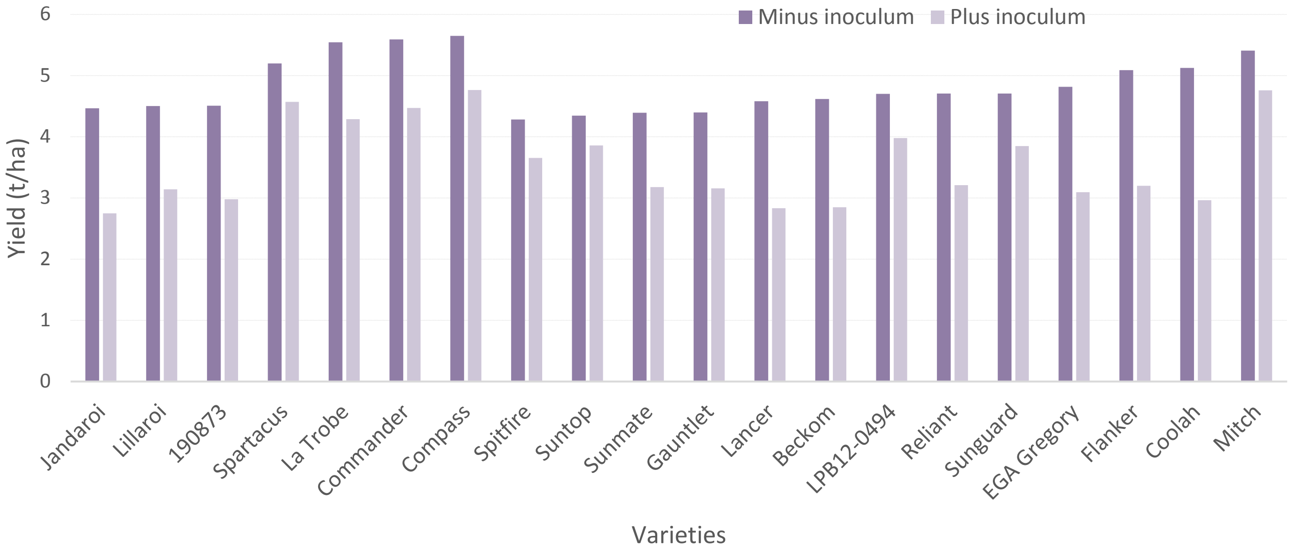

Figure 1. Yield comparisons for all varieties with and without crown rot inoculum added (lsd at P=0.05)

of the plots left untreated yielded higher than all of the plots with inoculum added. The only exceptions were Mitch$^{\Phi}$, Compass$^{\Phi}$, Spartacus$^{\Phi}$, Commander$^{\Phi}$ and La Trobe$^{\Phi}$ (one wheat and all the barley varieties).

The new varieties, LongReach Reliant$^{\Phi}$ and Coolah$^{\Phi}$ performed quite poorly, in the presence of crown rot the yield of these two varieties was reduced to 68% and 58% of the untreated yield respectively.

There were no consistent impacts of crown rot infection on grain protein levels across winter cereal types or varieties. The barley varieties did record significant differences in grain protein but two varieties recorded an increase in grain protein, Commander$^{\Phi}$ (0.60%) and Spartacus CL$^{\Phi}$ (0.63%) while the other two varieties recorded a decrease in grain protein, Compass$^{\Phi}$ (0.60%) and La Trobe$^{\Phi}$ (0.33%, not significant; Figure 2). For the bread wheat varieties there was only one significant change in grain protein with the addition of crown rot, LongReach Flanker$^{\Phi}$ increased by 0.40%. Jandaroi$^{\Phi}$ was the only other variety to record a significant change in grain protein, an increase of 1.14% in the presence of crown rot infection.

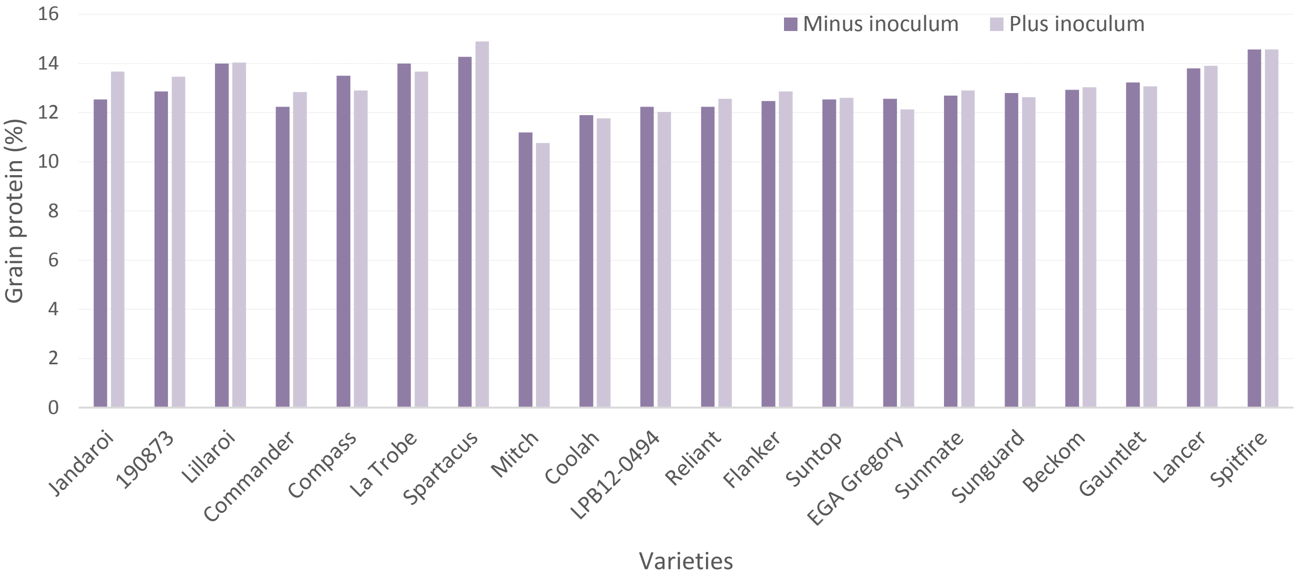

Figure 2. Grain protein comparisons for all varieties with and without crown rot inoculum added (lsd at P=0.05)

Implications for growers

The presence of crown rot will have a detrimental impact on yield regardless of the variety of wheat or barley grown. The potential yield loss can be reduced by selection of varieties that are more resistant to infection by *Fusarium pseudograminearum*. The best bread wheat options from this trial appeared to be Mitch$^{\phi}$, Suntop$^{\phi}$, LPB Spitfire$^{\phi}$ and Sunguard$^{\phi}$. As a group the barley varieties all had lower levels of yield loss compared to the durum varieties of between 12% and 23%. Conversely, the durum varieties suffered yield loss of between 30% and 38%.

Acknowledgements

This trial work was funded by the Grains Research and Development Corporation through the New South Wales Department of Primary Industries and the Department of Agriculture and Fisheries under project DAN00175.

Trial details

Location:	Meandarra
Crop:	Wheat, barley and durum
Soil type:	Vertosol
In-crop rainfall:	264.5 mm
Sowing date:	14 June 2016
Fertiliser at planting:	120 kg/ha urea 40 kg/ha Granulock® 12Z (Zn 2%)
Harvest date:	9 November 2016

Crown rot trial site at Meandarra

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Queensland's regional agronomy team conducts experiments that support agronomists and grain growers to make the best decisions for their own farms. The research summaries in this publication 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.