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Northern NSW research results 2017

RESEARCH & DEVELOPMENT – INDEPENDENT RESEARCH FOR INDUSTRY

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Northern NSW research results 2017

RESEARCH & DEVELOPMENT – INDEPENDENT RESEARCH FOR INDUSTRY

an initiative of Northern Cropping Systems

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Foreword

The NSW Department of Primary Industries (NSW DPI) Northern Cropping Systems group is excited to provide a snap shot of some of the results of their Research & Development (R&D) programs operating in cropping across northern NSW. The majority of this work is conducted in collaboration with our major investment partner, the Grains Research and Development Corporation (GRDC) to address key issues in the northern grains region.

The NSW DPI R&D teams based across the region; at Trangie, Tamworth, Narrabri and Grafton continue to conduct a range of experiments both at our research stations as well as at numerous on farm locations across the disciplines of plant breeding, agronomy, soils, nutrition, physiology and crop protection.

In this eighth edition, a collection of 46 short papers have been prepared to showcase some of the results of our work to you, our valued clients. This book continues to be a major source of information to advisors and growers across the northern grains region, hopefully providing some insight into potential strategies which are available for on farm implementation to increase profitability and industry viability.

These short papers have been written to improve the awareness and accessibility of the results from NSW DPI run research trials in the region. The papers are based on scientifically sound, independent research but need to be taken in the context of the situation and season that the work has been conducted. In many cases the research that is reported will prompt more questions and we encourage you to contact the authors to discuss any of these queries.

The work that is reported is only possible through the cooperation of the many growers, advisors and consultants who our research teams work with throughout the year and these contributions are acknowledged within each paper. We also collaborate with other research organisations including grower groups such as Grains Orana Alliance and Northern Grower Alliance, agribusinesses, universities, seed companies, research development corporations and other state based research providers.

Finally, we would like to thank the authors and editorial team for all their work compiling and reviewing the diverse range of papers in this year's edition.

We hope that you find the papers informative and of value to your business and we would welcome any feedback that you might have that would help us to continue to make the Northern NSW Research Results book a valuable resource into the future.

Loretta Serafin,

Leader, Dryland Systems North
On behalf of the Northern Cropping Systems Team

NSW Department of Primary Industries

Contents

Agronomy

Crop protection

Nutrition & Soils

Agronomy

Yield response of 32 bread wheat entries across three sowing dates – Trangie 2016

Greg Brooke, Tracie Bird-Gardiner and Jayne Jenkins
NSW DPI, Trangie

Key findings

- The quicker maturing varieties LRPB DartΦ, HatchetΦ LivingstonΦ, MaceΦ, SceptreΦ, MitchΦ and SuntopΦ were generally lower yielding than other entries at SD1, but were more yield competitive with other entries at SD2 and SD3.
- The longer season varieties EGA WedgetailΦ (6.08 t/ha) and EGA EaglehawkΦ (5.88 t/ha) were the highest yielding varieties at SD1, followed by CutlassΦ (5.51 t/ha) and LRPB FlankerΦ (5.36 t/ha).
- The mean yield at SD1 (4.89 t/ha) was not significantly different from SD2 (4.63 t/ha), but SD3 (3.56 t/ha) was significantly lower yielding than either SD1 or SD2.
- All varieties yielded their lowest from SD3.
- Protein percentages were low to moderate (mean of 9.8% for SD2 and 10.3% for SD1) with no significant difference from SD for any of the entries.

Introduction

Sowing date is a key driver of yield and variety performance. The optimum sowing time for an individual variety is a balance between having the variety flower too early and being subjected to frost damage, and conversely having it flower too late and experience prolonged heat stress. Both of these factors can have significant negative impacts on yield.

Site details

Location Trangie Agricultural Research Centre

Soil nutrition

Table 1. Soil chemical characteristics for 0–10 cm depth – Trangie 2016.

Characteristic	mg/kg
Ammonium nitrogen	11
Nitrate nitrogen	40
Phosphorus Colwell	42
Potassium Colwell	376
Sulfur	8.8
Organic carbon	1.07 (%)
pH_{Ca}	5.0

Starting nitrogen Total soil nitrogen level to 120 cm at sowing was 170 kg N/ha.

Rainfall The growing season rainfall was 545 mm (April to November).

Experiment design The experiment was a randomised block design that was blocked for the three sowing dates with varieties randomised within blocks. There were three replicates of each treatment.

Fertiliser	70 kg/ha Granulock® Z Extra treated with 400 mL/ha of flutriafol at sowing. 100 L/ha Easy N applied in-crop at early tillering and again after GS32, supplying a total of 85 kg N/ha.
Plant population	Target 100 plants/m^2
Weed management	Roundup CT® 1.5 L/ha + Boxer Gold® 2.5 L/ha + Logran® 30 g/ha applied before sowing. Axial® 100EC 200 mL/ha + Velocity® 1 L/ha applied in-crop.
Insect management	Fastac® DUO 125 mL/ha (alpha cypermethrin 100 g/L) applied in-crop to control aphids.
Disease management	Radial® 1.6 L/ha (azoxystrobin + epoxiconazole) applied at GS32 and Prosaro® (prothioconazole + tebuconazole) applied at GS39 to control rust.
Harvest date	25 November 2016

Treatments

Entries (32)

Twenty-eight released varieties and four advanced breeding lines as outlined in Table 1 and Figure 1.

Sowing date (SD)

SD1: 28 April 2016 (dry sown with rain on 30 April)

SD2: 17 May 2016

SD3: 30 May 2016

Results

Anthesis date

For SD1, Hatchet$^{\phi}$ was the first entry to reach anthesis (24 September) (Figure 1). After this date the coldest temperatures recorded for the rest of the growing season were 3.9 °C on 26 September; 3.3 °C on 28 September; 2.8 °C on 12 October and 3.7 °C on 23 October.

The new variety Coolah$^{\phi}$ followed very similar anthesis dates to EGA Gregory$^{\phi}$ for all three SDs.

The long-season, prime hard variety Suntime$^{\phi}$ was significantly earlier to reach anthesis than EGA Wedgetail$^{\phi}$ or EGA Eaglehawk$^{\phi}$ at each SD (Figure 1).

Grain yield and protein

At Trangie, which has a typically low rainfall and hot growing environment, the longer season varieties EGA Wedgetail$^{\phi}$ and EGA Eaglehawk$^{\phi}$ will normally only perform well from early and mid April sowing dates as they are too slow to flower when sown after these dates. However, in 2016 EGA Wedgetail$^{\phi}$ was the highest yielding variety in this experiment at SD1 (28 April) with 6.08 t/ha (Table 1) despite not flowering until 2 November (Figure 1). The yield performance of EGA Wedgetail$^{\phi}$ declined rapidly after SD1, producing 4.63 t/ha from SD2 (24% yield loss) and 3.64 t/ha from SD3 (41% yield loss; Table 1). EGA Eaglehawk$^{\phi}$ has also yielded well in other seasons from a mid April sowing and has been better than benchmark varieties such as the quicker maturing EGA Gregory$^{\phi}$ from that sowing date. However, similar to EGA Wedgetail$^{\phi}$, EGA Eaglehawk$^{\phi}$ yield rapidly declined after SD1 (Table 1).

LRPB Flanker$^{\phi}$ yielded 11% higher than EGA Gregory$^{\phi}$, the widely grown variety it is aiming to replace, at SD1. However, their yields were not significantly different for the two later sowing dates (Table 1).

Mitch⁽ᵇ⁾ and Beckom⁽ᵇ⁾ were generally higher yielding than many entries at SD3 and the only ones to yield above 4.0 t/ha with this later SD (Table 1).

Corack⁽ᵇ⁾, LRPB Dart⁽ᵇ⁾, Hatchet Plus⁽ᵇ⁾, LRPB Lancer⁽ᵇ⁾, Livingston⁽ᵇ⁾, LRPB Spitfire⁽ᵇ⁾ and UQ01553 exceeded mean grain protein levels for all three sowing dates (Table 1).

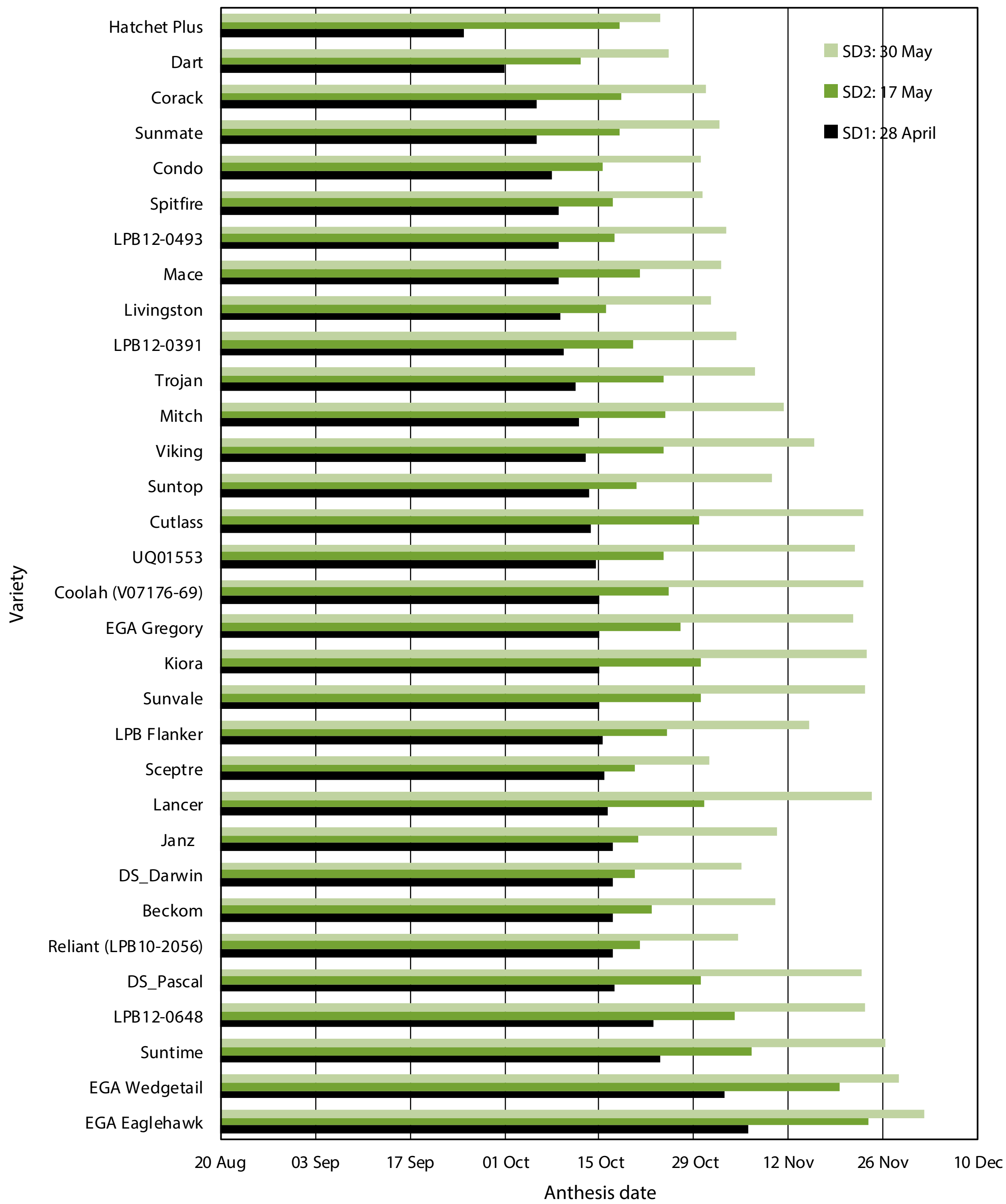

Figure 1. Anthesis (flowering) date of 32 wheat entries from three sowing dates – Trangie 2016
l.s.d (P<0.001) = 1.6 days.

Table 1. Grain yield and protein levels of 32 wheat entries sown on three sowing dates – Trangie 2016
l.s.d. (*P*<0.05) = 680 kg/ha).

Variety	Yield (t/ha)			Protein (%)		
	SD1 28 Apr	SD2 17 May	SD3 30 Apr	SD1 28 Apr	SD2 17 May	SD3 30 Apr
Beckom	5.54	4.83	4.01	9.4	9.8	9.2
Condo	4.91	4.55	3.38	10.2	10.1	10.5
Coolah	5.21	4.80	3.91	10.1	9.6	10.0
Corack	4.60	4.22	3.59	10.9	11.1	10.5
Cutlass	5.51	4.83	3.96	9.6	9.3	9.6
LRPB Dart	4.15	4.41	3.08	11.4	10.9	10.6
DS Darwin	4.84	4.37	3.17	10.8	10.2	9.9
DS Pascal	4.96	4.48	3.67	9.9	9.0	9.3
EGA Eaglehawk	5.88	4.93	3.78	9.4	9.6	10.1
EGA Gregory	4.83	4.44	3.17	10.2	9.9	10.1
EGA Wedgetail	6.08	4.63	3.54	9.7	9.4	10.4
Hatchet Plus	3.81	4.29	3.15	12.3	10.3	10.9
Janz	4.75	4.32	3.21	10.7	10.3	10.1
Kiora	4.96	4.87	3.51	10.0	9.2	10.0
LRPB Lancer	5.01	4.69	3.43	10.6	10.5	11.2
Livingston	4.22	4.35	2.98	11.2	10.4	10.4
LRPB Flanker	5.36	4.77	3.39	9.9	9.4	9.7
LPB12-0391	4.35	4.36	3.82	10.4	10.0	10.2
LPB12-0493	4.85	4.73	3.56	10.7	9.9	10.1
LPB12-0648	5.43	4.88	3.83	9.7	9.7	10.3
Mace	4.34	4.65	3.73	10.5	10.1	9.8
Mitch	5.03	5.17	4.02	9.0	8.5	8.9
LRPB Reliant	4.69	4.69	3.75	9.9	9.5	9.7
Sceptre	4.80	5.15	3.93	9.5	9.6	9.5
LRPB Spitfire	4.82	4.52	3.52	11.2	10.7	10.9
Sunmate	4.72	4.63	3.81	10.6	9.8	10.1
Suntime	4.94	4.56	3.52	9.5	9.7	10.3
Suntop	4.48	4.53	3.20	10.1	10.0	10.5
Sunvale	4.61	4.53	3.37	10.2	9.7	10.6
Trojan	5.31	5.20	3.68	9.5	9.2	9.7
UQ01553	4.81	4.09	3.39	10.6	10.1	10.6
LRPB Viking	4.83	4.47	3.70	10.6	9.7	9.9
Mean of SD	4.89	4.63	3.56	10.3	9.8	10.1
l.s.d	0.523			1.291		
c.v. (%)	11.6			0.92		

Conclusions

This experiment highlights the potential value of earlier sowing dates in this environment. Averaged across entries, there was a 27% yield decline when sowing was delayed until the end of May (SD3) compared with planting at the end of April (SD1). There was still an average yield decline of 23% when sowing was delayed from mid May (SD2) to the end of May (SD3).

Although the average yield of entries was not significantly different between SD1 and SD2 there were still some large differences for individual entries. EGA Wedgetail[(D)] (by 1.45 t/ha), EGA Eagkehawk[(D)] (by 0.95 t/ha), UQ01553 (by 0.72 t/ha), Beckom[(D)] (by 0.71 t/ha), Cutlass[(D)] (by 0.68 t/ha), LRPB Flanker[(D)] (by 0.59 t/ha) and LPB12-0648 (by 0.55 t/ha) were all significantly higher yielding at SD1 than at SD2 (Table 1). These are all mid–long season entries, which further highlights the potential value of matching maturity type to planned sowing date to maximise yield potential.

However, results from this sowing date experiment at Trangie in 2016 should be used with caution, as the season was atypically mild, wet and cool during the grain-filling period with few frosts. These conditions produced abnormal yield responses in some longer season varieties such as EGA Wedgetail⁽ᵗ⁾, but still highlights the extra yield potential (generally >1.0 t/ha) of these entries in favourable seasons.

Acknowledgements

This experiment was part of the project *Variety Specific Agronomy Packages for southern, central and northern NSW* (DAN00167), with joint investment by NSW DPI and GRDC. Technical assistance provided by Rachel Hayden (NSW DPI) and final editing by Dr Steven Simpfendorfer are gratefully acknowledged.

Wheat variety response to plant population and sowing date – Terry Hie Hie 2015

Rick Graham, Stephen Morphett, Jim Perfrement, Michael Dal Santo and Neroli Graham
NSW DPI, Tamworth

Key findings

- Sowing date, particularly for mid–late maturing varieties, was found to be a significant determinant of grain yield potential, with yield reductions of >25% observed due to a delayed sowing date (8 May vs. 7 June).
- Variety and sowing date in particular affected grain quality parameters, with a significant increase in the level of screenings for all varieties when the sowing date was delayed.
- Higher plant populations had a greater influence on grain yield when the sowing date was delayed. Yield potential was optimised at 200 plants/m^2 for a 7 June sowing date vs. 100 plants/m^2 for the earlier 8 May sowing date, supporting the principal of increasing targeted plant populations when sowing is delayed.
- Altering variety and maturity type, and increasing targeted plant population in response to a delayed sowing date did not fully compensate for yield losses associated with a delayed vs. timely sowing date.

Introduction

Wheat producers in northern NSW now have access to varieties with a range of maturities which, coupled with no-till farming systems, has lengthened the potential sowing window. It is also possible to achieve a high yield potential from a wide range of plant populations, given wheat's ability to adjust tiller numbers and head size in response to environmental conditions.

The question facing growers is what impact does variety choice, sowing date (SD) and plant population have on grain yield and quality (e.g. screenings).

Growers often query whether, if they sow an early-maturing variety later in the sowing window with an increased plant population, it can achieve comparable yield and grain quality potential as a mid–late maturing variety sown in the earlier part of the window.

Studies have often focused on yield potential, with grain quality a secondary consideration. Grain quality parameters such as screenings are, however, major causes of price downgrades and reduced profitability. Differences between wheat varieties to have a tendency to produce higher levels of screenings have been reported in previous studies.

The aim of this experiment at Terry Hie Hie on the north-western plains of NSW was to determine if there were differences between varieties with varying maturity types in terms of grain yield and quality parameters with different plant densities and sowing dates.

Site details

Location	'Part Anchor', Terry Hie Hie
Co-operator	Michael Ledingham
Soil type and nutrition	Grey vertosol
Previous crop	Wheat
Starting water	Approximately 161 mm of plant available water (PAW) to 120 cm when cored on 21 May (pre SD 2)
In-crop rainfall	Approximately 190 mm (May to November)
Starting nitrogen	Soil nitrate nitrogen (N) was approximately 63 kg N/ha (0–120 cm)
Trial design	A fully factorial, three replicate split plot design.
Fertiliser	40 kg/ha Granulock Z extra and 300 kg urea (140 kg N/ha) side banded at planting.

Harvest date	18 November 2015

Treatments

Varieties (6)	EGA Eaglehawk$^{\phi}$, EGA Gregory$^{\phi}$, LRPB Dart$^{\phi}$, LRPB Lancer$^{\phi}$, LRPB Spitfire$^{\phi}$, Suntop$^{\phi}$
Sowing date (SD)	SD 1: 8 May 2015 SD 2: 7 June 2015
Plant populations (PP)	PP 1: 50 plants/m^2 PP 2: 100 plants/m^2 PP 3: 200 plants/m^2

Results

Grain yield

There was a grain yield (GY) response to plant population for SD 1, but no population by variety interaction. Grain yield was optimised at a target plant population of 100 plants/m^2 with no significant difference (P<0.05) between 100 and 200 plants/m^2. Whereas, a population of 50 plants/m^2 resulted in approximately 400 kg/ha decrease in GY. LRPB Lancer$^{\phi}$, Suntop$^{\phi}$ and EGA Gregory$^{\phi}$ were the highest yielding varieties with LRPB Spitfire$^{\phi}$ the lowest yielding variety in SD 1, when averaged across population treatments (Table 1).

Table 1. Grain yield (t/ha), screening (%), thousand grain weight (g) and grain protein concentration (%) for six wheat varieties averaged across populations for the 8 May sowing date (SD1).

Variety	Grain yield (t/ha)	Screening (%)	Thousand grain weight (g)	Grain protein concentration (%)
LRPB Lancer	5.28^{a}	3.6^{a}	31.5^{a}	12.0^{b}
Suntop	5.18^{a}	8.9^{c}	31.1^{a}	11.4^{c}
EGA Gregory	5.09^{a}	6.4^{b}	31.2^{a}	11.3^{c}
EGA Eaglehawk	4.35^{b}	13.9^{d}	26.3^{b}	12.4^{ab}
LRPB Dart	4.11^{bc}	10.1^{c}	30.0^{a}	12.4^{ab}
LRPB Spitfire	3.89^{c}	8.6^{c}	31.4^{c}	12.8^{a}
l.s.d. (P = 0.05)	0.27	1.7	1.6	0.4

Values within columns with the same letters denote no significant difference

When looking at the grain quality parameters for SD 1, plant population had no effect on screenings (% grain below the 2.0 mm screen). There were, however, significant differences between the varieties (genotype effect) with screenings ranging from 3.6% for LRPB Lancer$^{\phi}$, averaged across treatments, up to 13.9% for EGA Eaglehawk$^{\phi}$. Importantly, apart from LRPB Lancer$^{\phi}$, all other varieties examined in this experiment in SD 1 exceeded the critical 5% screenings level which would have caused downgrading at receival (Figure 1). It is interesting to note that the thousand grain weight (TGW), a measure of kernel size, did not differ significantly between genotypes with the exception of EGA Eaglehawk$^{\phi}$. This indicates that differences in screenings could have been due to variations in kernel shape/plumpness or kernel weight stability.

In contrast to GY, grain protein concentration (GPC %) increased with decreasing plant population. The 50 plants/m^2 achieved a higher GPC than the targeted 200 plants/m^2, principally due to a yield dilution response where protein concentration in the grain is diluted by the extra starch accumulation (data not shown). Although GPC differed across varieties, there was no interaction between population and variety. Averaged across treatments, LRPB Spitfire$^{\phi}$ had the highest GPC, with varieties tending to be ranked inversely to their grain yield ranking (Table 1). It is, however, interesting to note that LRPB Lancer$^{\phi}$, although comparable in yield to both Suntop$^{\phi}$ and EGA Gregory$^{\phi}$, achieved a significantly (P<0.05) higher GPC than either of these varieties when averaged across treatments (Table 1).

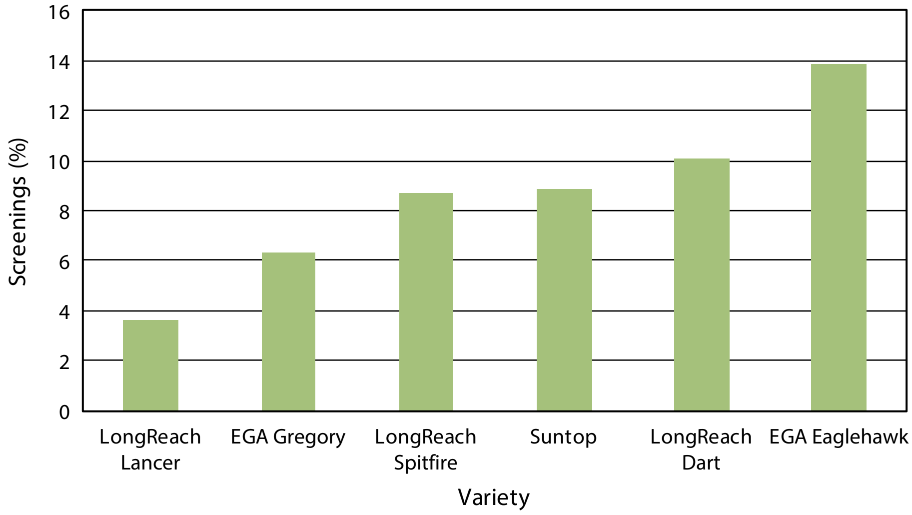

Figure 1. Mean grain screening (%) for wheat varieties, SD1 (8 May) Terry Hie Hie 2015. l.s.d. (P = 0.05) = 1.7%.

Although variety and variety by population differences were evident in the test weight data, the levels did not affect the minimum grain receival standard achieved. All varieties and population treatments exceeded the minimum test weight specification of 76.0 kg/hl.

Plant population had a significant effect on GY potential for SD 2. The 50 plants/m^2 treatment was significantly (P<0.05) lower yielding than both the 100 and 200 plants/m^2 treatments, with approximately 600 kg/ha difference between the 50 and 200 plants/m^2. Unlike SD 1, there was a yield difference between the 100 and 200 plants/m^2 treatments (Figure 2). This supported the accepted principal of increasing targeted plant populations with delayed sowing to maximise yield.

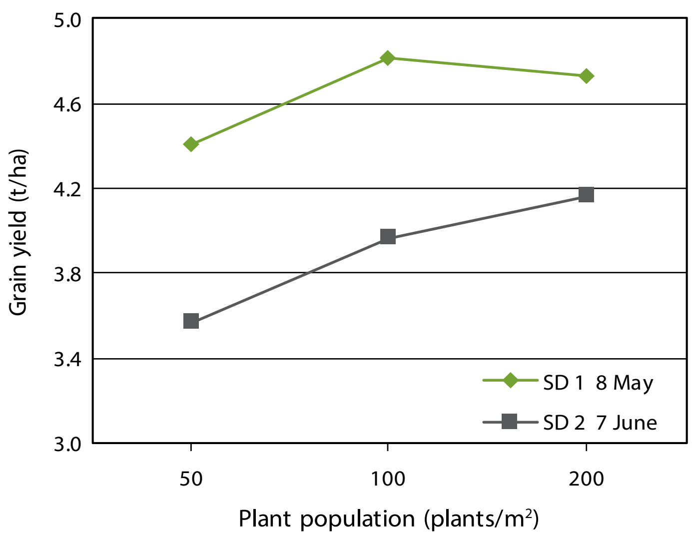

Figure 2. Mean grain yield (t/ha) response of wheat to plant population and sowing date, Terry Hie Hie 2015. SD1 l.s.d. (P = 0.05) = 0.18 t/ha, SD2 l.s.d. (P = 0.05) = 0.20 t/ha.

As per the SD 1 findings, there were no variety by population interactions; there were, however, significant differences in GY between varieties. Averaged across treatments, Suntop⍉ at 4.47 t/ha was the highest yielding variety significantly out yielding the next best performing, the early-maturing variety LRPB Dart⍉ by ~0.40 t/ha. Variety rankings differed in comparison with SD 1 (Table 2).

Table 2. Grain yield (t/ha), screening (%) and grain protein concentration (%) for six wheat varieties averaged across populations for 7 June sowing date.

Variety	Grain yield (t/ha)	Screening (%)	Grain protein concentration (%)
Suntop	4.47[a]	14.4[b]	12.5[d]
LRPB Dart	4.06[b]	19.2[c]	13.1[c]
LRPB Lancer	3.97[bc]	11.4[a]	13.5[b]
EGA Gregory	3.77[c]	13.9[b]	12.6[d]
LRPB Spitfire	3.73[c]	17.9[c]	13.9[a]
EGA Eaglehawk	3.38[d]	23.9[d]	13.5[b]
l.s.d. ($P = 0.05$)	0.28	2.3	0.2

Values within columns with the same letters denote no significant difference

When looking at grain quality parameters for SD 2, plant population had no effect on screenings (% grain below the 2.0 mm screen). There were, however, significant differences between the varieties, with screenings ranging from 11.4% for LRPB Lancer[(D)] averaged across treatments up to 23.9% for EGA Eaglehawk[(D)]. Importantly, delayed sowing resulted in a significant increase in screenings % for all varieties, with all exceeding the critical 5% level (Table 2). Thousand grain weight for all varieties was considerably lower when SD was delayed, with the reduced target plant population resulting in an increase in TGW (data not shown).

In contrast to yield, GPC increased when SD was delayed, highlighting the inverse relationship between GPC and GY, with lower yield potential and hence higher GPC associated with delayed sowing.

Conclusions

Results from this experiment highlight the importance of timely sowing, particularly for mid–late maturing varieties. Yield reductions of approximately 1.3 t/ha averaged across plant population treatments were recorded for the mid–late maturing varieties LRPB Lancer[(D)] and EGA Gregory[(D)] with delayed sowing, which equates to a 25% and 26% yield decline, respectively. Similarly, the late maturing variety EGA Eaglehawk[(D)] suffered a yield penalty of around 22% (0.98 t/ha) whilst the mid maturing variety Suntop[(D)] suffered a 14% (0.70 t/ha) yield reduction due to delayed sowing. In comparison, the earlier maturing varieties LRPB Dart[(D)] and LRPB Spitfire[(D)] suffered only minimal yield reductions when SD was delayed. Importantly however, the earlier maturing varieties did not exhibit any yield advantage over the later maturing varieties in SD 2 and were significantly lower yielding than these varieties at SD 1.

Temperature and plant available water during anthesis/grain fill would also have affected both yield potential and grain quality parameters, with limited effective in-crop rainfall in September/October, and temperatures exceeding 35 °C for an extended period from 4 October. The longer season variety EGA Eaglehawk[(D)] in particular had high screenings for both SDs, and also produced a low yield in SD 2, reinforcing the need to sow this variety early due to its lack of adaptability under unfavourable conditions.

Increasing plant population had a greater influence on GY when SD was delayed, with yield potential optimised at 200 plants/m^2 in SD 2 vs. 100 plants/m^2 in the earlier SD 1, supporting the principal of increasing targeted plant populations with delayed sowing. These findings further emphasise the advantage of planting early in the sowing window compared to delayed sowing just simply in terms of input seed requirements.

Variety selection and sowing date particularly affected grain quality parameters and screenings. There was a significant increase in the level of screenings for all varieties when sowing was delayed. LRPB Lancer[(D)] was the only variety in this experiment that achieved screenings of <5%, but only at SD 1. All other varieties, including LRPB Lancer[(D)] in SD 2, exceeded the critical 5% screenings receival standards level. LRPB Lancer[(D)] appears to have excellent grain stability with significantly lower screenings than either EGA Gregory[(D)] or Suntop[(D)]. Findings from this experiment indicate that there were differences between varieties in terms of grain stability, due possibly to variations in kernel shape/plumpness and or kernel weight stability. These results also highlight the adaptability of some of the mid–late season varieties, and the yield and quality advantages of sowing these varieties early, compared with sowing earlier maturing varieties later.

Acknowledgements

This experiment was part of the project *Variety Specific Agronomy Packages for southern, central and northern NSW* (DAN00167), with joint investment by NSW DPI and GRDC. Thanks to the Ledingham family for hosting the site and to Gav McDouall, HMAg for his assistance. Technical assistance provided by Jan Hosking, Peter Formann, Rod Bambach and Richard Morphett (all NSW DPI) is also gratefully acknowledged.

Re-evaluating seed colour change in canola to improve harvest management decisions – Tamworth 2016

Rick Graham, Rod Bambach, Jan Hosking, Stephen Morphett, Michael Dal Santo and Jim Perfrement
NSW DPI, Tamworth

Key findings

- Seed colour change (SCC) is slower to develop on branches compared with primary stems, with the primary stem only contributing ~22% of grain yield.
- Relying solely on SCC on the primary stem can underestimate overall seed development on the plant, negatively affecting seed size, oil concentration and yield potential.
- Windrowing earlier than 40% SCC on the primary stem was shown to reduce yield by up to 36% and oil concentration by 6.5%.
- Results clearly demonstrated the penalties associated with an early windrow timing, before 40–60% SCC on the primary stem, and the benefit of delayed windrow timings related to SCC, with yield optimised at the upper end of current industry guidelines.
- Ideally, SCC should be measured on a whole plant basis, not based solely on the primary stem, as branches contribute a large proportion of grain yield. There is also a further need for a clear definition as to what constitutes actual SCC in order to develop robust industry guidelines around windrow timing.

Introduction

Due to the increased prevalence of hybrid canola varieties, lower plant populations and perceived changes in plant architecture, there has been increased discussion in the canola industry about how best to determine seed colour change (SCC) and therefore windrow timing. Current industry guidelines, based on research conducted in the 1970s and 1980s, recommend that canola (*Brassica napus* L.) is ready to windrow when 40–60% of seeds on the primary (main) stem change colour from green to red, brown or black. The main issue of concern with this recommendation relates to the proportion of yield contained on the branches versus the primary stems, and the effect of the differential rate of seed maturity on yield and seed quality parameters.

In 2015, research started as a component of the GRDC co-funded 'Optimised canola profitability' project (CSP00187), to examine the relationship between SCC, grain yield and quality parameters, which aims to help growers make better informed decisions on canola harvest management in northern NSW, and potentially across Australia. These preliminary results indicated that there were large effects of where on the plant (branch vs. primary stem) SCC was measured. It was subsequently found from partitioning seed from pods that branches were slower to mature than the primary stems and that there was potential for significant yield and grain quality reductions associated with windrow timing. In 2016, a further series of experiments were conducted in the northern grains region (NGR) of NSW; findings from an experiment conducted at Tamworth in 2016 are outlined in this reported.

Site details

Location	Tamworth Agricultural Institute
Soil type	Grey vertosol
Previous crop	Barley
Starting soil water	~60 mm PAW to 120 cm
In-crop rainfall	~524 mm (May to October)
Starting nitrogen	Soil nitrate N was ~58 kg N/ha (0–120 cm)
Trial design	A replicated split plot design was used, with windrow timing as the main plot and variety randomised within the treatment timing plots.

Fertiliser	60 kg/ha Granulock Z Extra treated with Intake® (500 g/L Flutriafol at 200 mL/ha) and 360 kg/ha urea (160 kg N/ha) side banded at planting.
Sowing date (SD)	6 May 2016
Plant population	~30 plants/m^2

Treatments

Varieties (2)

Pioneer® 44Y89 (CL), Hyola® 575CL

Windrow timing

Windrow timings were conducted at 2–3 day intervals (i.e. Monday, Wednesday and Friday) from the start of SCC on the primary stem up until 100% SCC on branches. SCC was defined as when 'a minimum of two-thirds of the surface area of an individual seed changed colour from green to brown, red or black'. Actual SCC was determined using a representative 200 seed sub-sample, taken from pods from the middle third of the primary stem and randomly from across the branches of individual plants.

Results

Results focus on the overall effect of windrow timing and SCC on grain yield and oil concentration, rather than on varietal differences. It is, however, important to note that there were varietal differences that did influence the rate of seed development which, in turn, would influence management decisions around windrow timing. Both Pioneer® 44Y89 (CL) and Hyola® 575CL reached 50% flowering (i.e. ~50% plants with one flower open on the main stem) on 16 August. There were differences in how the varieties progressed from flowering to maturity, with Pioneer® 44Y89 (CL) faster to mature than Hyola® 575CL. Pioneer® 44Y89 (CL) reaching the end of flowering (5% flowers remaining) five days quicker than Hyola® 575CL (22 September vs. 27 September). As a result, SCC at any target timing for Pioneer® 44Y89 (CL) was more advanced and progressed more rapidly than Hyola® 575CL.

Seed colour change (SCC)

SCC and therefore, windrow timing treatments, started on 14 October at Tamworth in 2016. SCC was found to develop faster on the primary stem compared with branches. When looking at windrow timing averaged across the two varieties, it was observed that when SCC on the stems was at 61%, branches were only at ~20% SCC (windrow timing 7; Figure 1). These results also highlight how rapidly SCC can occur, with SCC on stems progressing from 18% to 61% at Tamworth in a 5-day period (windrow timing 5–7), in what was considered a very soft spring (Figure 1).

Seed size

Seed size, expressed as thousand seed weight (TSW), is an indicator of both physiological maturity and yield potential. When looking at changes in TSW over time at Tamworth (Figure 2) in relation to windrow timing, it was observed that differences in TSW stems *vs*. branches were largest during the earlier windrow timings reflecting differences in SCC and maturity. This would be expected given that seeds mature progressively up the primary stem from the lower branches to the upper branches, with changes in seed colour indicating declining metabolic activity and increasing seed maturity. At Tamworth in 2016, TSW for the branches and stems tended to plateau at ~60% SCC, which approximated 35% moisture content. Importantly, the optimum TSW for branches occurred with windrow timings later than current industry recommendations, which are based solely on SCC for the primary stem. This is significant given that branches contributed 78% of potential yield at Tamworth averaged across varieties.

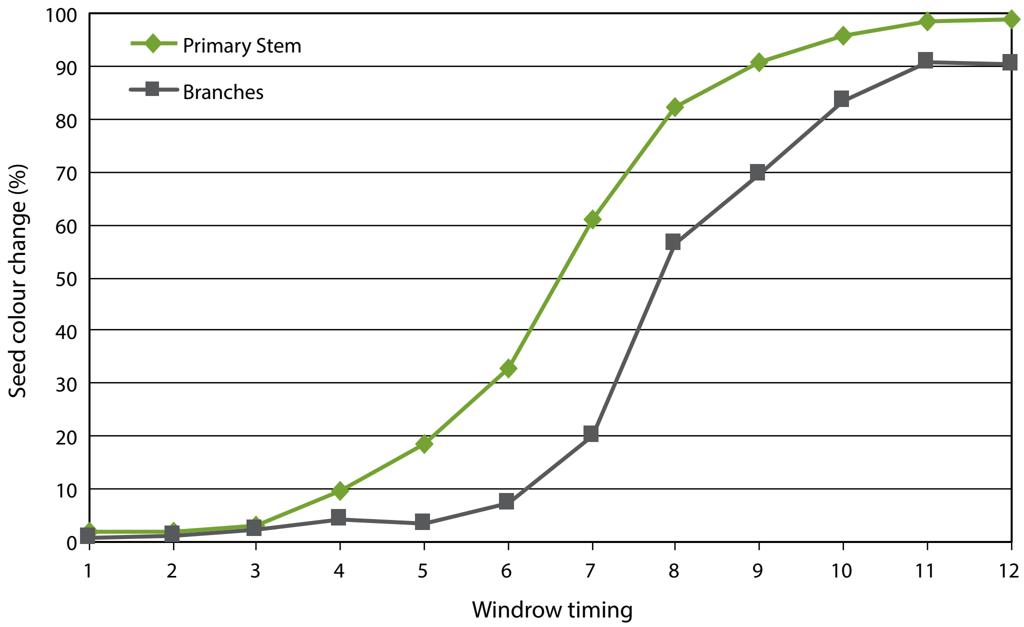

Figure 1. Seed colour change (%) primary stem vs. branches over time as determined by windrow timings at Tamworth in 2016. l.s.d. ($P = 0.05$) for primary stem = 14.2 % and l.s.d. ($P = 0.05$) for branches = 10.9 %.

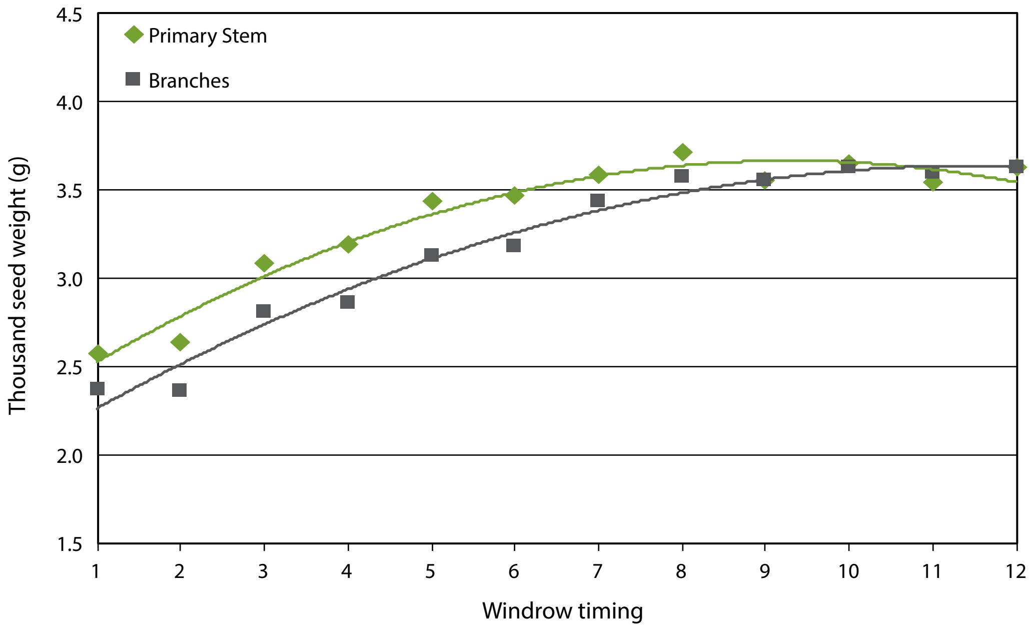

Figure 2. Changes in seed size (TSW) primary stem vs. branches over time as determined by windrow timing for Tamworth in 2016. l.s.d. ($P = 0.05$) for primary stem = 0.19 g and l.s.d. ($P = 0.05$) for branches = 0.15 g.

Grain yield

Windrowing when SCC started at Tamworth (timing 1) resulted in a 1.42 t/ha decline in yield potential, compared with windrowing at ~40–60% SCC on the primary stem (timings 6–7), which equates to a yield loss of ~36% (Figure 3). When considering the breakdown of yield components – primary stems *vs*. branches – it was observed that stems only contributed 22% of total grain yield averaged across windrow timings (data not shown). As was noted with SCC, seed sampled from the branches was less advanced than the primary stem, taking longer to reach physiological maturity. Grain size (TSW) for the branches plateaued at approximately 60% SCC (~timing 8) equating to a yield increase of ~0.20 t/ha or 5% over windrow timings 6 or 7.

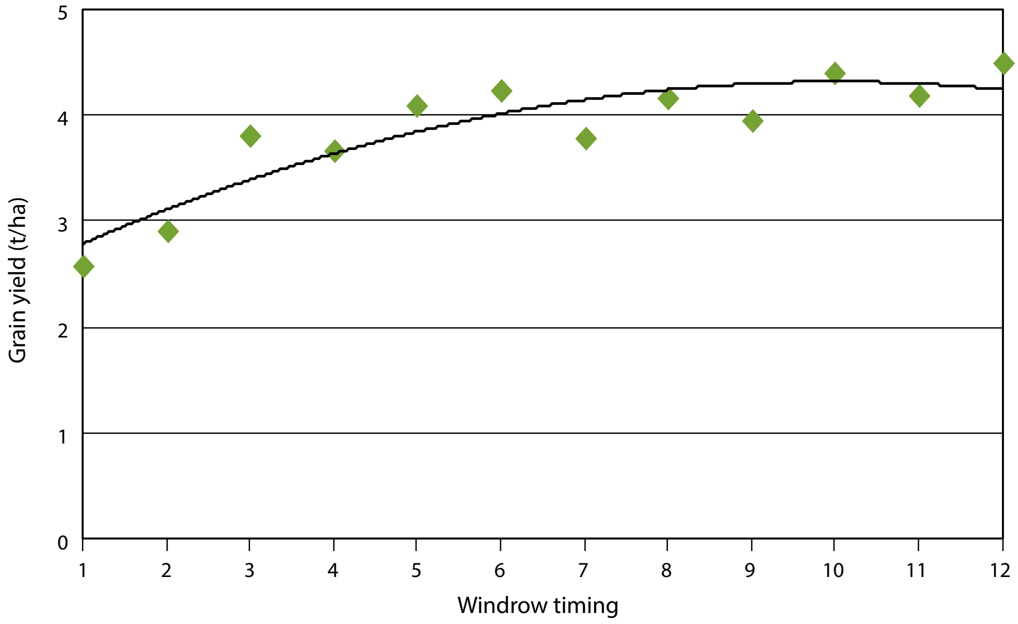

Figure 3. Effect of windrow timing/seed colour change on grain yield (t/ha) at Tamworth in 2016. l.s.d. ($P = 0.05$) = 0.54 t/ha.

Oil concentration

As per the grain yield response, there were significant oil concentration penalties for windrowing at early stages of SCC. At Tamworth, there was a 14% decline, or a 6.5% reduction in oil concentration (38.9% vs. 45.4%) when windrowing as SCC started versus windrowing at ~40% SCC on primary stems. There was also an increase in oil concentration where SCC was >60% on the primary stem, with increases in oil concentration of 0.6–2.0% (Figure 4).

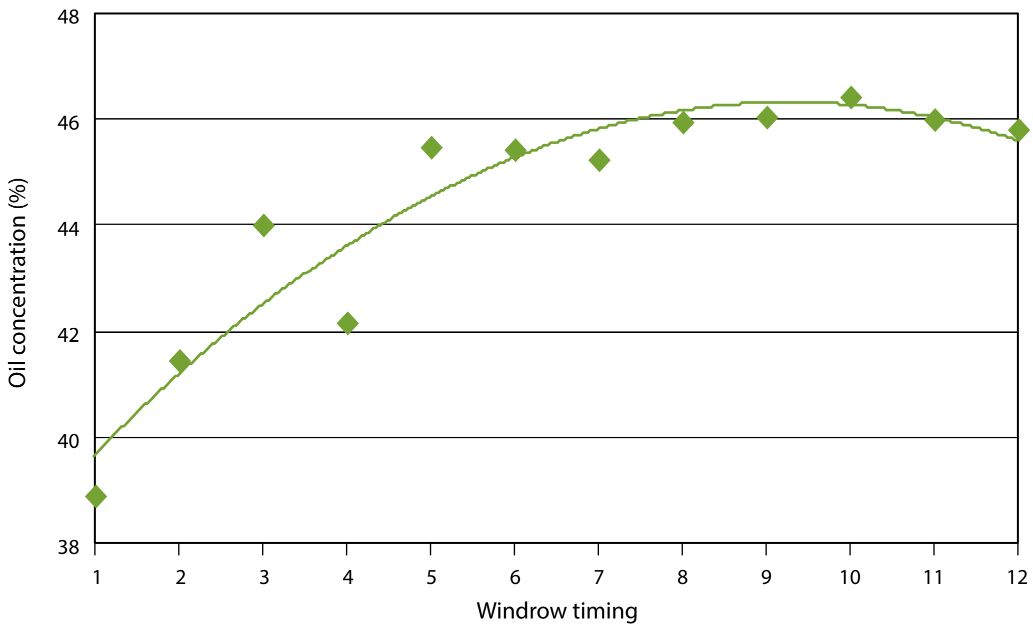

Figure 4. Effect of windrow timing/seed colour change on oil concentration (%) at Tamworth in 2016. l.s.d. ($P = 0.05$) = 0.57%.

Conclusions

Results from this experiment, underline the importance of correct windrow timing and the need to accurately determine SCC. It was observed, from partitioning seed from pods on the primary stem and branches that SCC was slower to develop on branches compared with stems. Importantly, in the yield components breakdown, it was found that seed from the primary stem only contributed ~22% of grain yield at Tamworth in 2016. If SCC on the primary stem is solely relied upon for windrowing decisions, overall seed development can be underestimated.

This can negatively affect seed size, oil concentration and yield potential. Furthermore, windrowing earlier than 40% SCC was shown to significantly reduce yield – by up to 36% and oil concentration by 6.5%.

Results clearly demonstrate the penalties associated with the current recommendation of early windrow timing at 40–60% SCC on the primary stem, and the benefit of delayed windrow timings related to SCC, with yield optimised at the upper end of current industry guidelines. Given the significance of the yield component contributed by the branches as opposed to stems, and with the increasing prevalence of hybrid varieties, lower plant populations, and associated changes in plant architecture, there would appear to be a need to reconsider the method of how SCC is determined.

This study demonstrates that SCC should ideally be measured on a whole plant basis and not solely on the primary stem. There is also a further need for a clear definition as to what constitutes actual SCC in order to develop robust industry guidelines around windrow timing.

Acknowledgements

This experiment was part of the project *Optimised canola profitability* (CSP00187), with joint investment by NSW DPI and GRDC, which is a collaborative project between NSW DPI, CSIRO and GRDC, in partnership with SARDI, CSU, MSF and BCG. Rohan Brill from NSW DPI is gratefully acknowledged for experiment design and for developing the research questions, technical guidance and protocol development; Dr Neroli Graham is thanked for biometric support.

Agronomic drivers of yield in rain-fed wheat production systems – Liverpool Plains

Rick Graham, Guy McMullen, Steven Simpfendorfer and Neroli Graham
NSW DPI, Tamworth

Key findings

- Sowing wheat varieties in the early part of their optimum sowing window was found to be a key determinant of yield. Delays in sowing date (SD) averaged across sites resulted in yield losses of 13% for EGA Gregory⁽ᴰ⁾ and ranged from 8% to 28%.
- Commercially available mid–late maturing spring wheat varieties (e.g. EGA Gregory⁽ᴰ⁾) were observed to be broadly adapted and plastic in their yield responses, performing consistently across sowing windows.
- Altering variety and/or maturity type, and increasing target plant populations in response to delays in SD could not fully compensate for the yield losses associated with delayed sowings.
- Yield responses to nitrogen (N) and phosphorus (P) fertiliser application rates, were variable and influenced by the starting soil nutrition and seasonal conditions.
- Crown rot (CR) was shown to be a significant factor influencing yield potential in inoculated *vs.* uninoculated experiments – the delayed SD decreased yields by 12%. Results highlight the compounding negative impact of delayed sowing and CR infection on yield potential and underline the need for awareness of risk levels from soil-borne pathogens before sowing in order to guide management decisions.

Introduction

It is currently estimated that growers in the Northern Grains Region (NGR) are achieving around 49% of water-limited yield potential (www.yieldgapaustralia.com.au). Water-limited yield potential is defined as the potential yield achieved under non-limiting nutrition and biotic stresses (e.g. plant pathogens) using best management practices, but subject to environmental constraints, namely plant available water and temperature. To put this into perspective, leading growers in Australia using best management practices and available technology are estimated to be achieving around 80% of water-limited yield potential, indicating that yield is being limited by factors other than available water. Based on these observations, there is an exploitable yield gap between actual and attainable yields i.e. 80% of water-limited yield potential. This is considered to be the approximation of where growers' yields plateau within most major cropping systems due to economic constraints and climatic variability.

Identifying the key drivers of yield in water-limited, rain-fed environments is clearly an important strategy for reducing the exploitable yield gap and for increasing dryland wheat production. The aim of this research was to benchmark yield potential across a range of growing environments in the NGR over two consecutive seasons, and to quantify the effect genotype (G), management (M) and environment (E) had on yield. Possible yield-limiting factors investigated included variety selection (maturity type), sowing date (SD), plant population and fertiliser inputs (nitrogen and phosphorus). In addition to these factors, crown rot, which is a major disease of wheat and barley crops in the NGR, caused by the fungus *Fusarium pseudograminearum* (*Fp*), was also incorporated into this study.

This report outlines findings from a series of dryland wheat experiments conducted on the Liverpool Plains of northern NSW in 2014 and 2015.

Site details

All sites were soil cored to ~1.2 m prior to sowing to determine plant available water capacities (PAWC) along with starting soil nutrition and other soil properties.

Locations	Site descriptions including site location, year of experiments and in-crop rainfall (May – October) are outlined in Table 1.
Soil type and nutrition	Soil type, starting soil nitrate nitrogen and Colwell P for each experiment are outlined in Table 2.

Trial design	A series of 36 treatment combinations (two sowing dates × 18 treatments) were examined in a partially factorial split-plot design, with three replicates at all sites (Table 3).

Table 1. Sowing date, growing season rainfall and plant available water holding capacity (PAWC).

Site and year	SD1	SD2	Growing season rain*(mm)	PAWC (mm)
Nowley 2014	14 May	1 July	174	~120
Mullaley 2015	20 May	8 July	185	~140
Tamarang 2014	9 May	30 June	170	~210
Tamarang 2015	19 May	9 July	252	~150

* May to October

Table 2. Soil type, starting soil nitrogen (nitrate N) and Colwell P.

Site and year	Soil type	P (Cowell) (mg/kg) 0–10 cm	Soil $N0_3$ (kg N/ha) 0–120 cm
Nowley 2014	Black vertosol	25	123
Mullaley 2015	Grey vertosol	46	178
Tamarang 2014	Brown vertosol	77	167
Tamarang 2015	Brown vertosol	60	213

Table 3. Summary of treatments: sowing date, variety, plant population, nitrogen and phosphorus rates and crown rot inoculum levels.

Treatment	Details	
Two sowing dates (SD)	SD1: early/main season	SD2: delayed
Four varieties	EGA Gregory (SD1 & 2) LRPB Spitfire (SD2)	Sunvale (SD1) LRPB Crusader (SD1 & 2)
Three targeted plant populations	60, 120 or 180 plants/m^2	
Five nitrogen rates	0, 50, 100, 150 or a 50 + 50 kg N/ha split application all applied as urea (46% N). Treatments were side banded at sowing, apart from the split application, which was applied at sowing and broadcast at stem elongation (GS31).	
Four phosphorus rates	0, 10, 20 or 30 kg/ha P applied as triple super at sowing	
Four crown rot inoculum rates	0, 0.5, 1.0 or 2.0 g/m row sterilised durum grain colonised by at least five different isolates of *Fp* ± added at sowing i.e. 0, CR+, CR++ or CR+++	

Treatments

Treatments were designed similar to an exclusion experiment, with a high input treatment (i.e. 100 kg N/ha, 120 plants/m^2, 20 kg P/ha) aimed at providing the perceived optimum combination of factors, and a low input treatment comprising a base set of agronomic factors to benchmark agronomic or management variables.

Four commercial spring wheat (*Triticum aestivum*) varieties widely grown and well adapted to targeted growing environments were selected and sown at each location. Varieties were from two different maturity groupings: two main season–moderate maturing varieties, EGA Gregory$^{(\phi)}$ and Sunvale$^{(\phi)}$; and two fast–moderate maturing varieties LRPB Crusader$^{(\phi)}$ and LRPB Spitfire$^{(\phi)}$. At each location, varieties were sown at two SDs: an early–main season and a delayed SD (Table 1). Plant populations were grouped as low, moderate (district practice) or high and were targeted at 60, 120 and 180 plants/m^2 respectively.

Results

The Liverpool Plains included the site locations of Tamarang, Mullaley and Spring Ridge, with all experiments conducted on vertosol soils (Table 2).

Sowing date

Yield results varied between site and year, and ranged from 5.91 t/ha at Tamarang in 2014 for SD1, to 2.62 t/ha at Spring Ridge for SD2 in 2014, averaged across treatments (Table 4).

Table 4. Mean site yield (t/ha) and corresponding yield range (t/ha) for two sowing dates averaged across varieties.

Site and year	SD1 mean	Range	SD2 mean	Range
Spring Ridge 2014	3.80	3.97–3.77	2.62	2.83–2.44
Mullaley 2015	4.34	4.38–4.21	3.56	4.00–3.06
Tamarang 2014	5.91	5.94–5.50	4.40	4.52–4.01
Tamarang 2015	4.23*	4.25–4.06	4.67*	4.93–4.29

* All SD contrasts significant ($P<0.05$) except Tamarang 2015.

When looking at the across-site analysis, timely sowing was found to be a significant driver of yield. Delays in SD reduced yields by 0.60 t/ha or 13.1% when comparing high input (100 kg N/ha, 120 plants/m^2, 20 kg P/ha) EGA Gregory$^{\phi}$ treatments (Table 5); yield declines ranged from 8% to 28%.

On an individual site basis, when comparing SDs for EGA Gregory$^{\phi}$, delays resulted in yield declines of 6.0 kg/day up to 28.8 kg/day. The only site not to show a yield response due to an earlier SD was Tamarang in 2015. This was most likely due to the impact of frost-induced sterility, with minimum temperatures of <0 °C occurring during the period from the 28 August to 1 September, coinciding with head emergence/anthesis, delivering a 14.5% decrease in EGA Gregory$^{\phi}$ yield between SD1 and SD2.

Table 5. Effect of management and crown rot (*Fp*) on grain yield potential – LPP across site analysis.

Variety	Population (plants/m^2)	Applied N (kg/ha)	Applied P (kg/ha)	*Fp* (CR+++)	Yield (t/ha)	Yield gap (t/ha)
SD1						
EGA Gregory	**120**	**100**	**20**	**0**	**4.57¥**	
EGA Gregory	120	100	20	+++	4.26	–0.31*
SD2						
EGA Gregory	**120**	**100**	**20**	**0**	**3.97¥**	**–0.60***
LRPB Crusader	120	100	20	0	3.65	–0.32*
LRPB Spitfire	120	100	20	0	3.55	–0.42*
LRPB Spitfire	120	100	20	+++	3.13	–0.84*

* Contrast are significant ($P<0.05$)

¥ EGA Gregory SD1 *vs*. SD2 contrast.

Variety

Maturity type was not a significant factor in SD1, with no difference (P<0.05) in yield between varieties. Variety choice did, however, affect yield in SD2, with EGA Gregory$^{\phi}$ significantly (P<0.001) out yielding both the quicker maturing varieties LRPB Crusader$^{\phi}$ and LRPB Spitfire$^{\phi}$ by 0.32 t/ha and 0.42 t/ha respectively. The yield contrast between EGA Gregory$^{\phi}$ at SD1 and LRPB Crusader$^{\phi}$ at SD2 equated to 0.92 t/ha or 20%, compared with 0.60 t/ha or 13.1% for EGA Gregory$^{\phi}$ at SD2.

Crown rot disease pressure

Increasing CR disease pressure (±*Fp* applied at sowing) resulted in a decreased yield for SD1 of 0.31 t/ha equating to a 7% decrease (Table 5). Similarly for SD2, CR also affected yield, with LRPB Spitfire$^{\phi}$ showing a 0.42 t/ha or 12% decrease in yield due to CR, when all other variables were held constant. Importantly, when contrasting the combined effects of SD, CR disease pressure and genotype, potential yield decreased by 1.44 t/ha or ~31.5%.

Nutrition

Varying N and P application rates had a limited effect on yield potential, most likely due to the relatively high starting soil N and Colwell P values at the sites (Table 2). There was a small, but significant, (P<001) response to P application rates (nil vs 30 units of P) of 0.17 t/ha (3.44 vs. 3.61 t/ha) for SD2 (data not shown). Interestingly, when looking at high input (100 kg N/ha + 20 kg P/ha) versus the low input treatments (nil N and P), there was a 0.31 t/ha or ~7% difference in yield for SD1 (data not shown). The only site to show a significant yield response to N application was Tamarang for SD1 in 2014, showing a 9% increase in yield with 100 kg N applied compared with the nil treatment.

Plant population

Results from the LPP showed that apart from Tamarang in 2014, where there was a yield response to increased plant population with delayed sowing, altering targeted plant population (Table 5) did not have a significant effect on yield, underscoring wheat's ability to compensate for lower plant populations, under good growing conditions.

At Tamarang in 2014, the low target population of 60 plants/m^2 was significantly ($P<0.05$) lower yielding at 3.67 t/ha than the 120 plants/m^2 and 180 plants/m^2 treatments at 4.01 t/ha and 4.04 t/ha respectively with a delayed SD, supporting the accepted principal of increasing targeted plant population with a delayed SD.

Conclusions

Timely sowing of broadly adapted bread wheat varieties in the early part of their optimum sowing window was found to be a key determinant of yield potential. The exception was the Tamarang site in 2015, however, all other sites demonstrated significant increases in yield with an early–main season sowing for SD1 vs. SD2 contrasts.

The LPP, with a mean predicted yield of 4.57 t/ha for EGA Gregory⟲ in SD1, had a 0.60 t/ha or 13.1% decrease in yield between SD1 and SD2 averaged across sites and years (Table 5). By delaying the SD, the growing environment is, in effect, being altered reducing the length of the growing season along with potentially the timing and extent of stresses, such as terminal drought or heat.

The adaptability or plasticity of mid–late maturing spring wheat varieties and yield stability across the sowing window was also demonstrated. On the LPP, the main season variety EGA Gregory⟲ performed well across SDs, out yielding faster-maturing varieties (LRPB Crusader⟲ and LRPB Spitfire⟲), even with delayed sowings. These findings support previous observations that commercially released Australian spring wheat varieties tend to be broadly adapted to a wide range of environments, with the best performing mid-season spring wheat variety for a region, often performing consistently across the main sowing window. This indicates that breeding companies are releasing more broadly adapted varieties that display good yield stability/plasticity across a range of growing environments.

Yield responses to N and P fertiliser application rates, were found to be variable and influenced by starting soil nutrition levels (relatively high starting soil N and Colwell P at some sites) and, to some extent, seasonal conditions (e.g. Tamarang in 2014). This highlights the value in determining starting soil nutrition levels through testing and considering critical nutrient response values (e.g. Colwell P) in fertiliser decisions. Nitrogen and P nutrition, based around predicted yield and critical soil values were, however, crucial in ensuring that optimum yield potentials were achieved.

Crown rot caused by the fungus *Fusarium pseudograminearum*, affected yield potential, decreasing yields by up to 12% on the LPP with delayed sowings. Timely sowing of wheat varieties in the early part of their sowing window increased yield potential and reduced the extent of yield losses from crown rot.

Acknowledgements

This research was part of the project *Northern region high yielding cereal agronomy – NSW* (DAN 00181), with joint investment by NSW DPI and GRDC. Technical assistance provided by Stephen Morphett, Jim Perfrement, Bruce Haigh, Peter Formann, Michael Dal Santo, Rod Bambach, and Jan Hosking (all NSW DPI) for the sowing, maintaining and harvesting the experiments is greatly appreciated.

The research undertaken as part of this project was made possible by the significant contributions of growers through both trial site cooperation and support of the GRDC, we would like to thank them for their continued support and in particularly David Ronald, James Vince and Richard Heath.

Agronomic drivers of yield in rain fed wheat production systems of Central West NSW – Trangie

Greg Brooke[1], Rick Graham[2], Guy McMullen[2], Steven Simpfendorfer[2] and Neroli Graham[2]
[1]NSW DPI Trangie
[2]NSW DPI, Tamworth

Key findings

- Sowing time for the wheat varieties was found to be the key determinant of yield potential. Delays in sowing date (SD) resulted in yield losses of 34% or 1.20 t/ha for EGA Gregory⊕ averaged across years.
- Variety selection was also found to be a significant factor influencing yield potential, with the longer season variety Sunvale⊕ being 16% or 0.6 t/ha lower yielding than LRPB Crusader⊕ from an early SD. The shorter season variety LRPB Crusader⊕ performed well across SD options in this environment.
- Increasing targeted plant populations was shown to increase yield potential by ~8% (0.2 t/ha) when SD was delayed, supporting the accepted principle of increasing the target plant population for delayed sowings.
- However, altering variety and/or maturity type, and increasing target plant populations in response to delayed SDs could not fully compensate for yield losses associated with delayed sowings.
- Yield responses to nitrogen (N) and phosphorus (P) fertiliser application rates were variable and influenced by starting soil levels and seasonal conditions. Significant yield responses of around 19% were achieved in response to P application, highlighting the importance of knowing starting soil nutrition values when trying to optimise yield potential.

Introduction

It is currently estimated that growers in the northern grains region (NGR) in NSW are achieving around 49% of water-limited yield potential (www.yieldgapaustralia.com.au). To put this into perspective, leading growers in Australia using best management practices and available technology are estimated to be achieving around 80% of water-limited yield potential indicating that yield is being limited by factors other than available water.

Water-limited yield potential is defined as the potential yield achieved under non-limiting nutrition and biotic stresses (e.g. weed competition) using best management practices, but subject to environmental constraints namely plant available water and temperature.

Based on these observations, there is an exploitable yield gap between actual and attainable yields (i.e. 80% of water-limited yield potential), which is considered the approximation of where grower's yields plateau within most major cropping systems, due to economic constraints and climatic variability.

Identifying the key drivers of yield in water-limited, rain fed environments is clearly an important strategy for reducing the exploitable yield gap and for increasing dryland wheat production. The aim of this research was to benchmark yield potential across a range of growing environments in the NGR of NSW, over two consecutive seasons, and to quantify the impact of genotype (G), management (M) and environment (E) on yield. Possible yield limiting factors investigated included variety selection (maturity type), sowing date (SD), plant population and fertiliser inputs (nitrogen and phosphorus). In addition to these factors crown rot, a major disease of wheat and barley crops in the NGR caused by the fungus Fusarium pseudograminearum (Fp), was also incorporated into this study.

This report outlines findings from dryland wheat experiments conducted at Trangie in the Central West of NSW in 2014 and 2015.

Site details

All sites were soil cored to ~1.2 m before sowing to determine plant available water capacities (PAWC), along with starting soil nutrition and other soil properties.

Locations

Site descriptions including site location, year of experiments and in-crop rainfall (May–October) are outlined in Table 1.

Table 1. Sowing date (SD), growing season rainfall and plant available water holding capacity (PAWC).

Site and year	SD1	SD2	Growing season rain* (mm)	PAWC (mm)
Trangie 2014	15 May	11 June	144	~67[1]
Trangie 2015	7 May	25 May	200	~76

*May to October.

[1]Estimation based on 25% of effective rainfall – November to March

Soil type and nutrition

Soil type, starting soil nitrate nitrogen and Colwell P for each experiment are outlined in Table 2.

Table 2. Soil type, starting soil N (nitrate N) and Colwell P.

Site and year	Soil type	P (Colwell) (mg/kg) 0–10 cm	Soil NO_3 (kg N/ha) 0–120 cm
Trangie 2014	Grey vertosol	76	94
Trangie 2015	Red-brown chromosol	23	127

Trial design

A series of 36 treatment combinations (two times of sowing × 18 treatments) were examined in a partially factorial split-plot design, with three replicates at each site (Table 3).

Table 3. Summary of treatments: sowing dates, variety, plant population, nitrogen and phosphorous rates and crown rot inoculum levels.

Treatment	Details
Two sowing dates (SD)	SD1: early/main season SD2: delayed
4 varieties	EGA Gregory⁽ᵈ⁾ (SD1 & 2), LRPB Spitfire⁽ᵈ⁾ (SD2), Sunvale⁽ᵈ⁾ (SD1), LRPB Crusader⁽ᵈ⁾ (SD1 & 2)
3 targeted plant populations	60, 120 or 180 plants/m^2
5 nitrogen rates	0, 50, 100, 150 or a 50 + 50 kg N/ha split application all applied as urea (46% N). Treatments were side banded at sowing, apart from the split application, which was applied at sowing and broadcast at stem elongation (GS31).
4 phosphorus rates	0, 10, 20 or 30 kg P/ha applied as triple super at sowing
4 crown rot (CR) inoculum rates	0, 0.5, 1.0 or 2.0 g/m row sterilised durum grain colonised by at least five different isolates of Fp± added at sowing i.e.; 0, CR+, CR++ or CR+++

Treatments

Treatments were designed similar to an exclusion experiment, with a high input treatment (i.e. 100 kg N/ha, 120 plants/m^2, 20 kg P/ha) aimed at providing the perceived optimum combination of factors and a low input treatment comprising a base set of agronomic factors to benchmark agronomic or management variables.

Four commercial spring wheat (*Triticum aestivum*) varieties widely grown and well adapted to the targeted growing environments were selected and sown at each location. Varieties were from two different maturity groupings: two main season-moderate maturing varieties EGA Gregory⁽ᵈ⁾ and Sunvale⁽ᵈ⁾ and two fast-moderate maturing varieties LRPB Crusader⁽ᵈ⁾ and LRPB Spitfire⁽ᵈ⁾. At each location, varieties were sown on two SDs: an early-main season and a delayed SD (Table 1). Plant populations were grouped as low, moderate (district practice), or high and were targeted at 40, 80 and 160 plants/m^2 respectively.

Results

Experiments were conducted over two consecutive years at the Trangie Agricultural Research Centre. In 2014, the experiment was conducted on a grey vertosol and in 2015 on a red–brown chromosol (Table 2).

Sowing date (SD)

Yield results varied between site and year, ranging from 4.24 t/ha for SD1 in 2015, to 1.82 t/ha for SD2 in 2014, averaged across treatments (Table 4).

Table 4. Mean site yield (t/ha) and corresponding yield range (t/ha) for two sowing dates (SD) averaged across varieties.

Site and year	SD1 mean	Range	SD2 mean	Range
Trangie 2014	3.07	3.07–2.74	1.82	1.92–1.72
Trangie 2015	4.24	4.49–3.59	3.04	3.35–2.74

* All SD contrasts significant (*P*<0.05)

Sowing time was shown to be a key driver of yield, with delayed sowing resulting in a 1.20 t/ha decrease in yield in the across-sites analysis, equating to a 34% decline for EGA Gregory⦶, SD1 vs SD2 (Table 5). When comparing individual site years, delays in SD resulted in yield declines of 42.5 kg/day in 2014 and 69.1 kg/day in 2015.

Table 5. Effect of management and crown rot (*Fp*) on grain yield potential – Trangie across site analysis.

Variety	Population (plants/m²)	Applied N (kg/ha)	Applied P (kg/ha)	*Fp* (CR+++)	Yield (t/ha)	Yield gap (t/ha)
SD1						
LRPB Crusader	80	100	20	0	3.78	
Sunvale	80	100	20	0	3.17	–0.61*
EGA Gregory	80	100	20	0	3.53[1]	ns
SD2						
EGA Gregory	80	100	20	0	2.33[1]	-1.20*
LRPB Spitfire	160	100	20	0	2.58#	
LRPB Spitfire	80	100	20	0	2.38#	–0.20*
LRPB Spitfire	40	100	20	0	2.14#	–0.44*

*Contrast are significant (*P*<0.05); ns = not significant

[1]EGA Gregory⦶ SD1 vs. SD2 contrast.

[#]SD2 contrasts relate to LRPB Spitfire⦶

Variety

Variety selection was found to be a contributing factor to yield potential for the earlier SD1, with the quicker maturing variety LRPB Crusader⦶ out-yielding the longer, main season variety Sunvale⦶ by 0.61 t/ha, with no significant difference between LRPB Crusader⦶ and EGA Gregory⦶ (Table 5). Importantly, SD2 results for Trangie in 2015 did show that the faster maturing variety LRPB Crusader⦶ was higher yielding than EGA Gregory⦶: 3.35 t/ha vs. 2.74 t/ha respectively (data not shown).

Crown rot (CR) disease pressure

Although increasing crown rot (CR) disease pressure (±*Fp* applied at sowing) did not result in a significant decline in yield, there was a trend of decreasing yield potential of approximately10% with increasing crown rot disease pressure (+*Fp*).

Nutrition

Varying N and P application rates had limited impact on yield potential, most likely due to high starting soil N and Colwell P values at the sites (Table 2). There was, however, a significant (*P*<0.01) yield response to P application with SD2 at Trangie in 2015 on a red–brown chromosol soil (Colwell P value of 23 mg/kg 0–10 cm), with a 0.54 t/ha increase in yield for

Agronomy

the 20 kg P/ha treatment over the nil P treatment with N held constant at 100 kg N/ha (data not shown).

Plant population

Plant populations (40, 80 or 160 plants/m²) had no effect on yield for SD1 at Trangie. In contrast, population had a significant (*P*<0.001) effect on yield when sowing time was delayed to SD2, with yield improving with increasing plant population (Figure 1). The low population treatment (40 plants/m²) was 0.44 t/ha or 17% lower yielding with the 80 plants/m² approximately 8% or 0.20 t/ha lower yielding than the high population (160 plants/m²), with a significant difference between all treatments (Table 5).

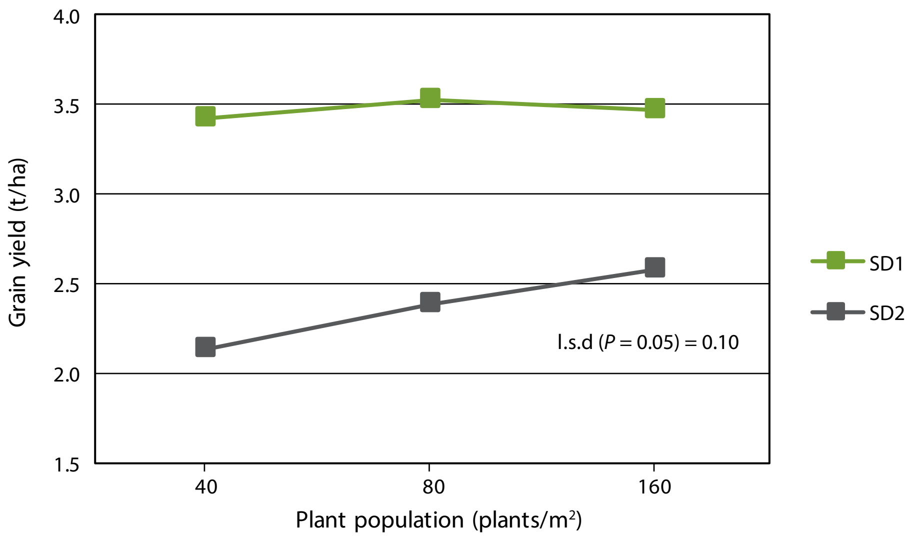

Figure 1. Yield response of wheat to plant population and sowing date – Trangie across site analysis.

Conclusions

Sowing time was found to be the key determinant of yield potential at Trangie with the yield for EGA Gregory⁽ᵈ⁾ declining by 34% (1.2 t/ha) averaged across years. The importance of timely sowing in this environment was also evident when looking at yield declines over time. In 2014, a 27-day delay in SD resulted in a yield decline of 42.5 kg/ha per day, with a delay in SD of 18 days in 2015, resulting in a yield decline of 69.1 kg/ha per day. These results underline that when SD is delayed, the growing environment is, in effect, being altered, reducing the length of the growing season along with potentially the timing and extent of environmental stresses, such as terminal drought or heat.

Variety selection was also shown to be a significant factor influencing yield potential, with the longer season variety Sunvale⁽ᵈ⁾ 16% or 0.6 t/ha lower yielding than LRPB Crusader⁽ᵈ⁾ for SD1. LRPB Crusader⁽ᵈ⁾ showed a trend for increased yield potential over EGA Gregory⁽ᵈ⁾ with a delayed SD.

Increasing targeted plant populations was shown to increase yield potential when the SD was delayed at Trangie, supporting the accepted principle of increasing targeted plant populations for delayed sowings. At Trangie, for example, for SD2 the yield increased with higher plant populations, with the high targeted population of 160 plants/m², out yielding the low (40 plants/m²) and the district practice rate (8 plants/m²) by 17% (0.44 t/ha) and ~8% (0.20 t/ha) respectively. Importantly however, changing variety selection in response to delayed SDs and increasing targeted plant populations could not fully compensate for yield losses associated with delayed sowing. These findings further highlight the advantage of sowing well-adapted varieties, in the early part of their optimum sowing window, and also highlights wheat's ability to compensate for lower plant populations under adequate growing conditions (i.e. SD1).

Yield responses to N and P fertiliser application rates at Trangie, were variable and influenced by starting soil levels (comparatively high starting soil N and Colwell P) and, to some extent, seasonal conditions. Importantly however, there was a significant yield response of ~19% or

0.54 t/ha to 20 units of P in 2015, on a soil with a Colwell P value of 23 mg/kg 0–10 cm. This result highlights the importance of knowing your starting soil nutrition values (e.g. Colwell P) when making fertiliser decisions.

Acknowledgements

This research was part of the project *Northern region high yielding cereal agronomy – NSW* (DAN 00181), with joint investment by NSW DPI and GRDC. Technical assistance provided by Paddy Steele, Lizzie Smith, Sally Wright and Ray Platt (all NSW DPI) for the sowing, maintaining and harvesting of experiments is greatly appreciated.

Effect of sowing date on phenology and grain yield of 19 bread wheat and five durum cultivars – Tamworth 2016

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NSW DPI, Tamworth

Key findings

- Cooler spring temperatures and excellent plant available soil moisture, favoured the yield potential of longer season and mid maturing wheat varieties in 2016.
- The mid–late and mid-season bread wheat varieties Suntime⁽ᴾ⁾, LRPB Flanker⁽ᴾ⁾, Suntop⁽ᴾ⁾, Beckom⁽ᴾ⁾, Mitch⁽ᴾ⁾ and EGA Gregory⁽ᴾ⁾ all performed well from an April 27 sowing date (SD1) with yields >6.5 t/ha. The new long-season spring type Sunmax⁽ᴾ⁾, likewise achieved ~6.5 t/ha.
- The longer season bread wheat varieties LRPB Kittyhawk⁽ᴾ⁾ and Sunlamb⁽ᴾ⁾ also demonstrated their yield potential, achieving yields >6 t/ha for SD1.
- Varieties that performed well across the three sowing dates included EGA Gregory⁽ᴾ⁾, Mitch⁽ᴾ⁾, LRPB Flanker⁽ᴾ⁾, Suntop⁽ᴾ⁾ and Beckom⁽ᴾ⁾.
- The new mid-fast season variety LRPB Reliant⁽ᴾ⁾ yielded well from a main season and delayed sowing date.
- Warm autumn temperatures resulted in many spring wheat entries, particularly the more temperature responsive cultivars, reaching anthesis faster (days from effective SD to anthesis) for SD1 compared with SD2. LRPB Lancer⁽ᴾ⁾ for example was ~9 days faster to reach anthesis for SD1 vs SD2.
- The advanced durum line AGT D043 performed well, achieving yields comparable to the best performing durum DBA Aurora⁽ᴾ⁾ and bread wheats from a main season sowing date.

Introduction

The autumn break and subsequent sowing window in Northern NSW can occur anytime between March and June, with the reliability of the break often more inconsistent compared with Southern NSW. Increasingly, varieties with large differences in maturity have been released by breeding programs. These vary in phenology from slow developing winter types, to fast developing spring varieties. These varietal phenology differences enable late-maturing varieties (winter and slow spring types) to be sown when the break is early, and earlier maturing varieties such as fast spring types, to be sown when there is a late break which, when coupled with no-till farming systems, has increased the length of sowing opportunities.

The combination of phenology and sowing date (SD) determines the probable timing of environmental stresses (frost and heat stress) at key developmental stages, such as anthesis and during the critical post-flowering grain-fill period. The optimum flowering window is considered an agronomic compromise between avoiding excessive yield loss due to frost and ensuring that flowering occurs early enough to enable a long grain-fill period, before heat and moisture stress restrict yield potential.

Variety response to SD experiments help to determine how new varieties compare in maturity and yield with existing varieties across the sowing window at a regional level. This provides data to better inform growers about varietal response to SD options and therefore to better match variety with SD. Overtime, these experiments provide greater confidence in varietal performance estimates and flowering behaviour.

This experiment reports the effect of three sowing dates on the timing of anthesis, grain yield and grain quality parameters for a range of commercially available and advanced bread wheat and durum varieties.

Site details

Location	Tamworth Agricultural Institute
Soil type	Brown vertosol
Previous crop	Sorghum, long fallowed
Sowing	Direct drilled using twin disc openers on 33 cm row spacing.
Starting nitrogen	Soil nitrate N was approximately 91 kg N/ha (0–120 cm)

In-crop rainfall	550 mm (May to October)
Irrigation	15 mm applied 28 April to establish first SD only
Trial design	A fully factorial, three replicated, split plot design, with four sowing dates.
Fertiliser	60 kg/ha Granulock Z extra and 195 kg urea (90 kg N/ha) side banded at planting.
Harvest date (HD)	HD1 and HD 2: 30 November 2016 HD3: 14 December HD4: 18 December

Treatments

Varieties (24)

Nineteen bread wheat and five durum cultivars commercially available or advanced breeders' lines (Table 1).

Sowing date (SD)

SD1: 27 April 2016
SD2: 17 May (Effective 27 May)
SD3: 17 June
SD4: 29 July

Plant populations (PP)

Targeting 100 plants/m^2

Results

Seasonal overview

Although growing season rainfall (May to October) was 550 mm (90 percentile range), with record monthly rainfall totals for June and September recorded, early sowing conditions were less than ideal. Total rainfall received, March to April inclusive, was 28 mm, with only 4.8 mm received in April. As a consequence SD1 on the 27 April was dry sown and received a post sowing irrigation of ~15 mm, using a low pressure dripper system to encourage establishment.

In contrast, SD2 was dry sown on the 17 May but did not receive a post sowing irrigation, which meant that its effective sowing date was the 27 May, the date when in-crop rain was received.

SD3 on 17 June was compromised by waterlogged conditions, receiving over 80 mm in the 72-hour period immediately post sowing. This resulted in an average plant establishment of only 53 plants/m^2, a 55% reduction in establishment, compared with SD1, SD2 and SD4 with ~95 plants/m^2. As a consequence, results from SD3 are not presented.

Phenological response to sowing date

The warm autumn temperatures resulted in many spring wheat entries, particularly temperature-responsive cultivars, reaching anthesis faster (days from effective SD to anthesis) in SD1 compared with SD2 (Table 1). Conversely, the cooler spring temperatures appeared to extend the days to flowering for many of these varieties with delayed sowing (SD2).

The phenological differences between the durum varieties evaluated were comparatively small compared with the bread wheat entries. Of the durum lines evaluated (SD1), the advanced breeder's line 190873 was approximately 9–11 days faster to reach anthesis compared with the other cultivars evaluated (113 days vs. 122–124 days; Table 1). This difference in developmental maturity was largely maintained for SD2 (117 days vs. 125–127 days), with all durum varieties flowering within two days of each other at the delayed SD4 on 29 July (89 vs. 99 days).

Table 1. Grain yield and days to anthesis for 23* wheat lines sown over three sowing dates – Tamworth 2016.

Variety	Sowing date								
	27 April			27 May			29 July		
	Grain yield (t/ha)	Yield rank	Days to anthesis	Grain yield (t/ha)	Yield rank	Days to anthesis	Grain yield (t/ha)	Yield rank	Days to anthesis
Beckom	6.60	4	114	6.11	7	117	4.55	9	96
EGA Gregory	6.59	6	123	6.17	4	125	5.24	1	96
LRPB Dart	5.09	19	104	5.31	18	110	4.39	11	85
LRPB Flanker	6.73	2	123	6.03	8	125	4.80	4	96
LRPB Gauntlet	5.65	16	119	4.99	20	122	3.65	22	96
LRPB Kittyhawk	6.40	8	142	5.45	16	139	3.60	23	106
LRPB Lancer	5.77	14	123	5.40	17	132	4.37	12	99
LRPB Reliant	5.94	11	118	5.97	9	117	4.88	3	91
LRPB Spitfire	5.75	15	115	5.95	10	118	3.65	21	91
LRPB12-0494	5.97	10	114	5.87	14	117	4.62	6	91
Mitch	6.60	5	123	6.28	3	127	4.92	2	96
Sunguard	5.48	18	122	5.31	19	123	3.67	19	96
Sunlamb	6.17	9	147	5.88	13	145	4.59	7	99
Sunmate	5.85	13	107	5.89	12	117	4.09	17	91
Sunmax	6.49	7	145	6.38	1	141	4.36	13	99
Suntime	6.77	1	129	5.92	11	134	4.28	15	99
Suntop	6.69	3	115	6.29	2	123	4.65	5	91
SUN 760B	5.00	20	106	5.83	15	115	4.29	14	89
190873**	4.12	21	113	4.87	21	117	3.67	20	89
AGT D043**	5.92	12	124	6.11	6	125	4.56	8	91
Caparoi**	3.55	22	123	4.35	23	125	4.20	16	91
DBA Aurora**	5.62	17	122	6.13	5	125	4.41	10	91
DBA Lillaroi**	3.36	23	123	4.45	22	127	4.09	18	91
l.s.d Grain yield ($P = 0.05$) = 0.66 t/ha									

* One advanced bread wheat line was excluded from the data set.

** Denotes durum wheat entries

In contrast to the durum wheats, there were much greater differences in the phenological responses to SD in the bread wheats. This was particularly pronounced when comparing the fast maturing spring variety LRPB Dart(D) with the newly-released APH classified winter wheat LRPB Kittyhawk(D). When sown on the April 27 (SD1), LRPB Dart(D) reached anthesis on 18 August, compared with 26 September for LRPB Kittyhawk(D), a difference of 39 days. This highlights the differences in phenology of the bread wheat varieties now available to growers, that is, a fast spring wheat, with minimal response to vernalisation (e.g. LRPB Dart(D)) compared with a winter wheat that has a defined vernalisation requirement (e.g. LRPB Kittyhawk(D)).

Apart from winter types, northern NSW growers also have available to them APH-classified slow spring types such as Sunmax(D). When looking at response to sowing date from a 27 April planting (SD1), Sunmax(D) reached anthesis in ~145 days (29 September) compared with ~123 days (September 7) for both EGA Gregory(D) and LRPB Lancer(D).

Interestingly, when looking at differences in days to reach anthesis with a delayed sowing (SD1 vs. SD2), LRPB Lancer(D) took seven days longer to reach anthesis from SD2 (132 days) compared with EGA Gregory(D) (125 days). This highlights the accelerated maturity of LRPB Lancer(D) due to its responsiveness to temperature compared with EGA Gregory(D). Other bread wheat entries that showed accelerated development (days to reach anthesis) in response to temperature: >6 days: (SD1 vs. SD2), included Suntop(D), Sunmate(D) and LRPB Dart(D) (Table 1). Suntime(D), a longer season spring type, also appeared to respond to the warmer autumn/winter temperatures, and although six days later to reach anthesis compared with EGA Gregoryᶲ at SD1, was nine days later to flower at SD2.

Varieties that were not as responsive to temperature, that is, did not differ greatly in days to reach anthesis (SD1 vs. SD2), included LRPB Reliantᶲ, EGA Gregoryᶲ, LRPB Flankerᶲ and LRPB Gauntletᶲ.

These results highlight the influence of seasonal conditions on wheat phenology, and underscore the importance of sowing date experiments.

Grain yield

The cooler spring temperatures and excellent plant-available soil moisture, generally favoured higher yield potential in the longer season, and mid maturing bread wheat cultivars.

The delayed SD2 (27 May) did not incur a yield penalty, which is often associated with delayed flowering (Figure 1). There was no significant difference (*P*<0.001) in the mean grain yield of SD1 and SD2 (5.69 t/ha vs. 5.67 t/ha).

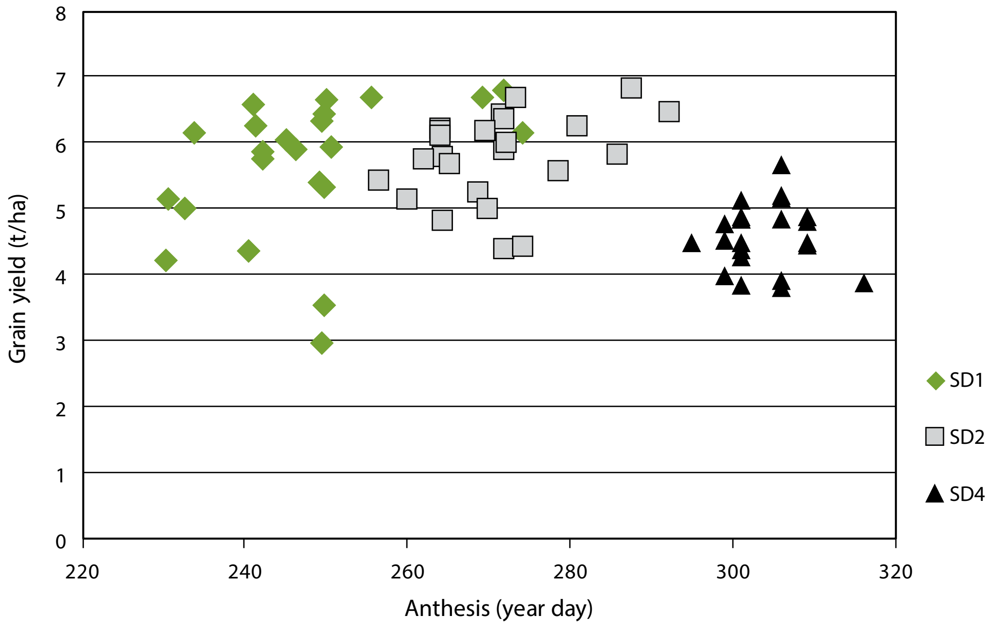

Figure 1. Year day of anthesis and grain yield for 24 wheat entries sown at three sowing dates – Tamworth 2016.

Despite SD4 (29 July) being extremely late, the mean yield was still 4.33 t/ha, a further reflection of the atypical growing season experienced at this site in 2016. It was also observed that despite the late SD, none of the faster maturing spring types were able to achieve significant yield advantages over the mid maturing varieties.

Mid-season and mid-late varieties namely Suntimeᶲ, LRPB Flankerᶲ, Suntopᶲ, Beckomᶲ, Mitchᶲ, and EGA Gregoryᶲ all performed well from SD1, with yields >6.5 t/ha (Table 1).

Despite the 27 April (SD1) being towards the end of the preferred sowing window for the longer season varieties Sunmaxᶲ, LRPB Kittyhawkᶲ and Sunlambᶲ, these varieties still demonstrated their yield potential, all achieving yields greater than 6.0 t/ha (Table 1).

The risk associated with sowing a fast-maturing line early was highlighted when comparing the yield of the breeder's line SUN760B, a fast spring type sown well outside its preferred sowing window (SD1), compared with the more favourable window of SD2. There was a yield loss of ~14% from SD1 vs. SD2 or 5.00 t/ha vs. 5.83 t/ha respectively. Similarly, the mid-fast maturing advanced durum line 190873 experienced a significant (P<0.001) yield decline of 0.75 t/ha (~15%) for SD1 compared with SD2 (4.12 t/ha vs. 4.87 t/ha), most likely due to frost-induced sterility.

Varieties that performed well across SDs included EGA Gregory⟨Φ⟩, Mitch⟨Φ⟩, LRPB Flanker⟨Φ⟩, Suntop⟨Φ⟩ and Beckom⟨Φ⟩. The new mid season variety LRPB Reliant⟨Φ⟩ also did well, particularly from a main season sowing (SD2) and demonstrated good yield potential from a delayed sowing (SD4), increasing its ranking relative to other varieties (Table 1).

The mid maturing durum variety DBA Aurora⟨Φ⟩ performed well from early (SD1, 27 April) and main season (SD2, effective 27 May) sowings, with yields of 5.62 t/ha and 6.13 t/ha respectively. This experiment also highlighted the yield potential of the advanced durum line AGT D043, which achieved yields of 5.92 t/ha and 6.11 t/ha from SD1 and SD2 respectively, and was comparable to the best performing bread wheat entries from a main season sowing (SD2; Table 1).

Grain quality

Although not discussed in detail, grain protein concentration (%), screenings (% grain above 2 mm slotted screen), test weight (kg/hL) and thousand grain weight (TGW) are presented in Table 2.

Table 2. Grain quality parameters for 23* wheat lines sown over three sowing dates – Tamworth 2016.

Variety	Sowing date											
	27 April				27 May				29 July			
	Grain protein (%)	Screening (%)	TGW# (g)	Test weight (hl/kg)	Grain protein (%)	Screening (%)	TGW# (g)	Test weight (hl/kg)	Grain protein (%)	Screening (%)	TGW# (g)	Test Weight (hl/kg)
Beckom	10.9	0.8	37.0	81.3	11.0	1.5	35.7	83.3	12.5	2.0	33.0	76.7
EGA Gregory	11.4	0.8	45.2	83.6	11.4	1.8	44.0	84.5	11.8	1.0	38.3	78.6
LRPB Dart	12.8	1.6	39.8	79.8	12.5	2.6	38.8	81.0	12.8	3.8	33.8	70.4
LRPB Flanker	10.6	0.7	44.9	83.4	11.2	1.7	44.6	84.7	11.9	1.2	38.1	79.3
LRPB Gauntlet	11.1	1.2	43.0	81.7	12.2	2.4	42.4	82.1	13.3	1.1	37.4	79.0
LRPB Kittyhawk	10.7	2.3	39.3	84.9	11.7	1.4	42.8	80.8	13.3	8.4	26.8	72.0
LRPB Lancer	11.7	1.1	42.0	82.7	12.2	1.5	39.8	83.4	13.8	0.9	35.8	78.6
LRPB Reliant	11.5	1.5	44.9	82.6	11.5	2.6	44.9	83.7	11.7	1.3	40.7	79.4
LRPB Spitfire	13.1	0.7	47.9	82.3	12.8	1.6	44.1	83.3	14.1	2.4	40.5	77.4
LRPB12-0494	11.3	1.4	40.2	80.9	11.7	2.6	42.4	82.0	12.4	1.6	38.6	77.9
Mitch	10.3	0.9	46.2	81.3	10.4	1.3	46.2	82.4	11.3	1.1	38.4	77.5
Sunguard	11.5	1.2	40.2	81.7	12.2	2.7	38.2	81.4	13.1	2.9	32.1	78.1
Sunlamb	10.4	5.7	33.1	81.2	11.8	5.3	32.8	74.0	13.3	4.0	29.7	74.4
Sunmate	11.7	2.0	43.3	79.8	11.6	2.3	43.2	81.9	12.5	1.1	41.6	76.5
Sunmax	9.9	3.2	37.9	83.2	11.2	2.0	41.2	80.7	13.5	1.6	39.3	77.0
Suntime	10.9	1.8	39.2	83.1	11.4	1.8	38.9	82.9	13.3	2.5	34.5	78.1
Suntop	11.0	1.7	40.4	82.3	11.4	1.8	40.4	83.2	12.5	1.5	38.7	78.8
SUN 760B	12.5	0.9	42.7	78.6	12.4	1.1	45.1	81.6	13.5	0.7	40.1	74.5
190873**	13.2	0.7	53.7	80.5	13.0	0.8	53.0	81.7	13.2	0.4	47.3	73.5
AGT D043**	11.4	0.8	50.7	83.5	11.3	1.2	53.4	84.9	12.1	0.8	45.2	77.0
Caparoi**	14.6	0.5	55.9	80.9	13.7	0.7	57.8	82.1	13.2	0.3	48.4	74.1
DBA Aurora**	12.0	0.9	54.9	81.5	11.6	1.3	56.3	83.2	12.3	0.9	42.9	72.8
DBA Lillaroi**	14.9	0.4	55.4	80.0	14.2	0.5	57.0	80.4	13.0	0.3	49.7	75.7
l.s.d Grain protein ($P = 0.05$) = 0.5												
l.s.d Screenings ($P = 0.05$) = 0.1												
l.s.d TGW*** ($P = 0.05$) = 2.3												
l.s.d Test weight ($P = 0.05$) = 1.8												

* One advanced bread wheat line was excluded from the data set.

** Denotes durum wheat entries

\# TGW – thousand grain weight

As a consequence of the high yields achieved, grain protein concentration (GPC) results were comparatively low, due in part to the yield dilution response, (i.e. GPC declining with increasing yields). A number of varieties (e.g. Mitch$^{\phi}$) did have difficulties achieving 12% GPC for SD1 and SD2, while there also appears to be some evidence of varietal differences in terms of GPC achievement, as indicated by the differences between varieties at comparable yields (Table 2).

Screenings for all varieties with the exception of LRPB Kittyhawk$^{\phi}$ for SD4 and Sunlamb$^{\phi}$ for SD1 and SD2 were below the 5% receival standards, again reflecting the favourable and extended grain filling conditions at this site in 2016.

Most varieties were able achieve the minimum test weight receival standard of 76 kg/hl, with test weight as expected tending to be an issue only for some varieties in the delayed SD4.

Grain size expressed as TGW (g/1000 seeds) was generally excellent, with most bread wheats around 40 g/1000 seeds for SD1 and SD2, and the durum wheats around 50 g/1000 seeds.

Differences in screenings (%) and/or TGW between varieties could indicate an increased potential for downgrading due to screenings under less favourable conditions.

Conclusions

There was no significant yield penalty for delayed sowing between SD1 vs. SD2, with the mean grain yields of 5.69 t/ha and 5.67 t/ha achieved. Yields of >4 t/ha averaged across varieties were achieved from a late sowing on 29 July (SD4), a further indication of the atypical growing conditions experienced at this site in 2016.

Long season varieties that performed well at this site in 2016 included the new slow-maturity spring wheat Sunmax$^{\phi}$, the winter type LRPB Kittyhawk$^{\phi}$ and the dual purpose variety Sunlamb$^{\phi}$, all achieving yields of >6 t/ha from the end of their optimum sowing window (27 April, SD1). Mid-late and mid season varieties, namely Suntime$^{\phi}$, LRPB Flanker$^{\phi}$, Suntop$^{\phi}$, Beckom$^{\phi}$, Mitch$^{\phi}$ and EGA Gregory$^{\phi}$, all yielded well from SD1, with yields >6.5 t/ha.

Varieties that performed well across sowing dates included EGA Gregory$^{\phi}$, Mitch$^{\phi}$, LRPB Flanker$^{\phi}$, Suntop$^{\phi}$ and Beckom$^{\phi}$, with the new mid fast season variety LRPB Reliant$^{\phi}$ performing well, particularly from a main season sowing (SD2), and demonstrating good yield potential from a delayed sowing (SD4).

Of the durum lines evaluated, the mid maturing durum variety DBA Aurora$^{\phi}$ yielded well from early (SD1, 27 April) and main season (SD2, effective 27 May) sowings, with yields of 5.62 t/ha and 6.13 t/ha respectively. The advanced durum line AGT D043 also showed promising yield potential, achieving yields of 5.92 t/ha and 6.11 t/ha respectively for SD1 and SD2, comparable with the best performing bread wheat entries from a main season (SD2) sowing.

When looking at bread wheat phenology responses to SD, the warm autumn temperatures in 2016 resulted in many spring wheat entries, particularly temperature-responsive cultivars, reaching anthesis faster (days from effective SD to anthesis) for SD1 compared with SD2. LRPB Lancer$^{\phi}$ for example, took 123 days to reach anthesis for SD1, the same as EGA Gregory$^{\phi}$, while it took 132 days to reach anthesis from SD2 (27 May), which was seven days later than EGA Gregory$^{\phi}$ at 125 days.

Varieties that were not as responsive to temperature, that is, did not differ greatly in days to reach anthesis between SD1 and SD2, included LRPB Reliant$^{\phi}$, EGA Gregory$^{\phi}$, LRPB Flanker$^{\phi}$ and LRPB Gauntlet$^{\phi}$. These results highlight the influence of seasonal conditions on wheat phenology, and underscore the importance of sowing date experiments.

Acknowledgements

This experiment is part of the project *Variety specific agronomy packages* (VSAP; DAN 00167), with joint investment by NSW DPI and GRDC. Technical assistance provided by Jan Hosking, Peter Formann, Rod Bambach, Jim Perfrement, Tyson Peterswald and Natalie Aquilina (all NSW DPI) is also gratefully acknowledged.

Evaluation of new soybean varieties for the Macquarie Valley – Trangie Agricultural Research Centre, 2013–2016

Leigh Jenkins
NSW DPI, Trangie ARC

Key findings

- Soybean yield potential ranged from a low of 1.01 t/ha up to a high of 2.94 t/ha in two years of harvested irrigated variety evaluation experiments at Trangie in the Macquarie Valley.
- Delayed sowing of a soybean crop in the Macquarie Valley can increase the likelihood of delayed maturity, potentially running into prolonged periods of wet autumn weather at harvest time; the 2015–16 experiment was not able to be harvested for this reason.
- Moonbi$^{\phi}$ (released 2010) is the recommended variety for Macquarie Valley soybean growers under fully irrigated conditions. It has high yield potential, maturity adaptation, excellent grain quality to meet human consumption markets, and resistance to powdery mildew.
- Djakal (southern NSW variety) is recommended for partial irrigation or dryland situations. Its earlier maturity and lodging resistance due to shorter height and reduced biomass enables it to achieve high yields and human consumption quality under less favourable growing conditions.

Introduction

The Northern Pulse Agronomy Initiative (NPAI) was established as a joint project between NSW DPI and GRDC in 2013. A key outcome from this project is to develop management packages that lead to greater adoption, productivity and profitability of both winter and summer pulses in the northern grains region of NSW. Identifying and understanding the constraints that limit potential productivity will lead to more reliable pulse crops, allowing seasonal yield potential and quality characteristics to be achieved.

Soybean is a versatile summer-growing rotation crop with dual benefits: being a legume plant that can contribute nitrogen to the soil profile; and also producing an oilseed grain crop. It has a longer growing season than mungbean and is traditionally grown in rotation with either winter cereals (double-cropped) or summer cereals (sorghum and maize).

Soybean crops are particularly profitable where the quality standards for human consumption markets are attained. Developing improved Australian varieties with better grain quality has led to improved profitability of soybean as a stand-alone crop, in addition to its rotational benefits as a pulse crop. However, production in the Macquarie Valley region (central west NSW) is limited by competition from other summer crops (particularly cotton) and a lack of current knowledge regarding best management practice for new varieties.

Through the support of the NPAI project, NSW DPI conducted soybean variety evaluation experiments (in collaboration with more variety-specific agronomy experiments) at Trangie Agricultural Research Centre (Trangie ARC) for three consecutive summer seasons (2013–14, 2014–15 and 2015–16), to assess if new soybean varieties for the Macquarie Valley under irrigated conditions were a suitable option for growers.

Soybean seed for these experiments was sourced from two separate NSW DPI breeding and evaluation programs. The northern program (based at Grafton) selects lines suited to the North Coast, Northern Tablelands and northern inland regions of NSW. Released lines include Moonbi$^{\phi}$, Richmond$^{\phi}$ and Hayman$^{\phi}$: these round-leaf varieties tend to have a more vigorous growth pattern and longer maturity. The southern program (based at Yanco) selects lines more suited to southern NSW regions, particularly the Riverina and Lachlan Valley irrigation regions. Released lines include Djakal, Snowy$^{\phi}$ and Bidgee$^{\phi}$. Characteristics include a more oval-shaped leaf, shorter plant height, reduced biomass and much quicker maturity when compared with northern lines.

Varieties from both programs tend to display different adaptation patterns (such as flowering, biomass, height, and maturity) when grown in the central NSW Macquarie Valley region. All recently released varieties target human consumption markets.

Site details

Location	All three experiments were conducted at Trangie ARC.
Soil type	Grey vertosol.
Irrigation	Full flood irrigation schedules, including pre-irrigation before planting and in-crop irrigation as required during the growing season.
Row spacing	These experiments were all planted on standard row spacing of 33 cm.
Plant population	Sowing rates were adjusted for each variety's individual seed size to achieve a consistent plant density of 40 plants/m^2 for all varieties.
Trial design	Randomised complete block design with three replications.

Treatments

Table 1. Soybean trial treatment list 2013 -2016.

Treatment	2013–14 season	2014–15 season	2015–16 season
Variety	12 varieties: Bidgee Cowrie Djakal M056-9 Moonbi N005A-29 N005A-80 P168-5 P176-14 Richmond Snowy Soya 791	14 varieties: Bidgee Bowrie Djakal M094-15 Moonbi N116C-3 N258A-4 N005A-80 P168-9 P176-1 P176-14 P176-2 Snowy T176A-4	18 varieties: Bidgee Bowyer Djakal M094-15 Moonbi N005A-80 P176-1 P176-14 P176-2 P213-41 P213-44 Snowy T171C-3 T171C-4 T176A-4 T257C-1 T257C-32 T257C-6
Sowing date	25 Nov 2013	16 Dec 2014	16 Dec 2015
Harvest date (days after sowing – DAS)	9 April 2014 (135 DAS)	6 May 2015 (141 DAS)	not harvested due to wet weather for six weeks

Results

2013–14 season

- The mean yield in 2013–14 was 1.58 t/ha (1.01–2.06 t/ha).
- Moonbi⟨PBR⟩ (northern line released 2010) was the highest yielding variety (2.06 t/ha) but was not significantly different from Djakal (southern industry standard) or two experimental lines P168-5 and P176-14.
- Richmond⟨PBR⟩ (northern line released 2013) was significantly lower yielding than Moonbi⟨PBR⟩ and was found to be too late in maturity for the Macquarie Valley region; this variety was subsequently not evaluated in the next two season's experiments.
- Snowy⟨PBR⟩ and Bidgee⟨PBR⟩ (named southern varieties) were both significantly lower yielding than the southern industry standard variety Djakal.
- Cowrie and Soya 791 were included as traditional Macquarie Valley standards. Cowrie was outclassed by both Moonbi and Djakal, while Soya 791 was not harvested due to extremely late maturity and hence was also not included in the next two season's experiments.
- The mean seed size (measured as 100-seed weight) was 14.25 g (11.44–16.31 g).

- In this experiment, all the experimental lines showed significant improvement in seed size compared with most of the released (named) varieties.
- The grain quality attributes, including oil and protein content, were assessed by commercial laboratory techniques for this experiment (data not included).

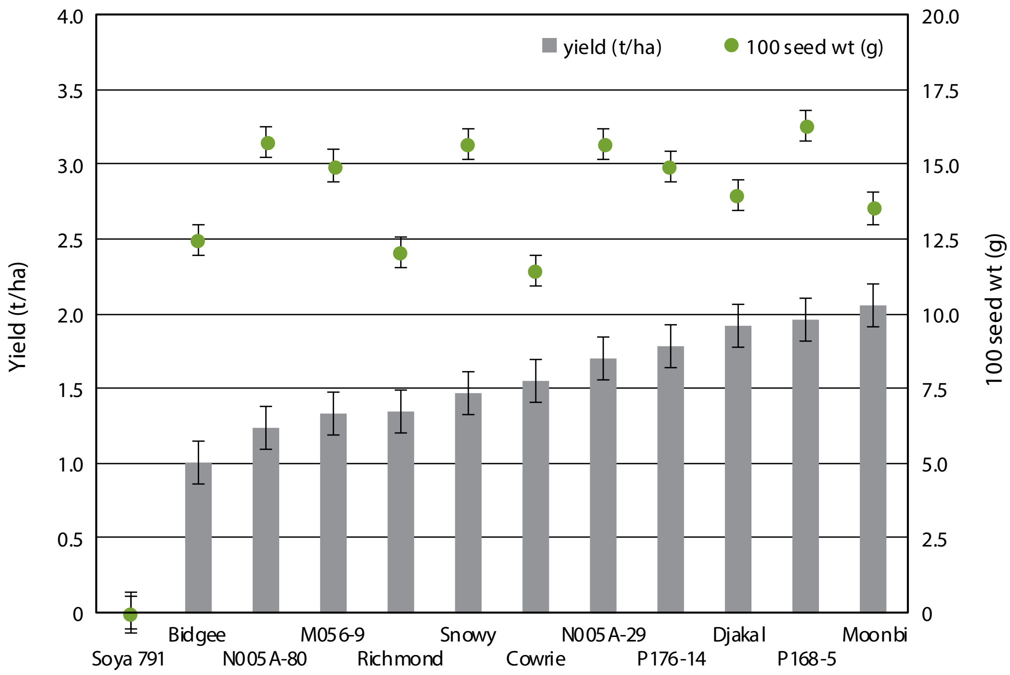

Figure 1. Grain yield (t/ha) and 100-seed weight (g) for 12 varieties of soybean at Trangie ARC, 2013–2014 season. l.s.d. yield (P<0.001) = 0.29 t/ha; l.s.d. 100-SW (P<0.001) = 1.06 g.

2014–15 season

- The mean yield in 2014–15 was 1.93 t/ha (1.23–2.94 t/ha).
- Moonbi⦸ (2.94 t/ha) was significantly higher yielding than 12 of the other 13 varieties, the exception being one experimental line M094-15 from the northern breeding program, which was not evaluated in the previous season.
- While Snowy⦸ and Djakal were not significantly different for yield in this experiment, Bidgee⦸ was significantly lower yielding than 12 other varieties including Snowy⦸ and Djakal.
- Bowyer was included as a superseded variety from southern NSW, now outclassed due to lower yield potential and lower human consumption quality.
- The mean seed size (measured as 100-seed weight) was 19.80 g (16.54–26.71 g).
- In this experiment, seed size was considerably larger compared with the previous season's results.
- T176A-4 (an experimental line from northern breeding program) had significantly larger seed size than all other 13 varieties.
- Flowering dates were recorded for the 2014–15 experiment. For southern varieties F50% dates were Bidgee⦸ – 22 January (37 DAS), Snowy⦸ – 25 January (40 DAS), and Djakal – 26 January (41 DAS); the northern variety Moonbi⦸ was at F50% on 5 February (51 DAS).
- Peak biomass was measured by quadrant cuts on 30 March (37 days pre-harvest) with a mean biomass of 2700 kg/ha for all varieties. Moonbi⦸ had the highest mean biomass of all varieties (4100 kg/ha), but otherwise in this experiment there was a very poor correlation (data not shown) between peak biomass and harvested yield.
- The grain quality attributes, including oil and protein content, were assessed by commercial laboratory techniques for this experiment (data not included).

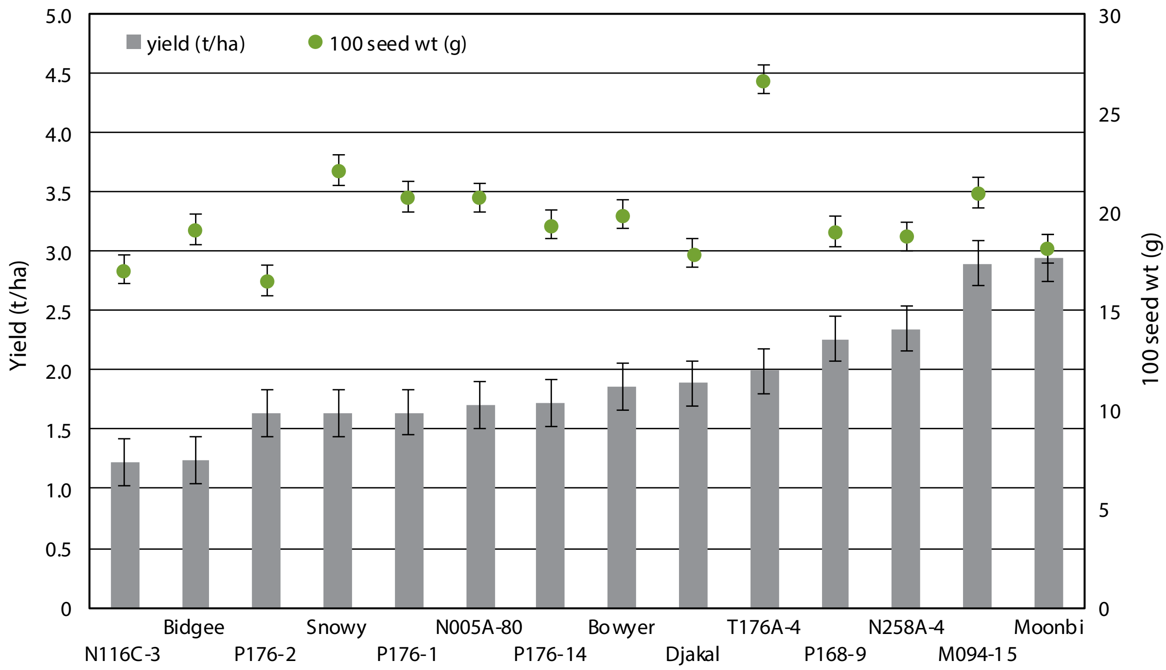

Figure 2. Grain yield (t/ha) and 100-seed weight (g) for 14 varieties of soybean at Trangie ARC, 2014–2015 season. l.s.d. yield (P<0.001) = 0.39 t/ha; l.s.d. 100-SW (P<0.001) = 1.48 g

2015–16 season

- This experiment was not harvested, however, F50 flowering dates, P95 (physiological maturity) dates and seed size data were recorded.
- Varieties from the southern-based program (Bidgee⁽ᴰ, Snowy⁽ᴰ and Djakal) were at F50% flowering on or about 1 February (47 DAS), whereas varieties from the northern-based program (Moonbi⁽ᴰ and other northern experimental lines) were at F50% flowering on or about 10 February (56 DAS).
- The southern lines started to mature (based on P95 data) from 11 April to 22 April, whereas the northern lines succumbed to wet weather before reaching P95 (physiological maturity) on about 25 May.
- The grain samples were collected from pods in the field to assess seed size. Mean seed size (measured as 100-seed weight) was 20.37 g (17.69–23.19 g), but in this experiment no single variety was largely different in seed size; T176A-4 was at the lower end of the range in contrast to the previous season's results (data not shown).
- The other grain quality attributes (oil and protein content) were not able to be assessed for this experiment.
- Heavy rain at the end of April and early–mid May 2016 caused significant seed loss due to shattering in the almost-mature southern lines, and failure to mature in the northern lines. The experiment was abandoned as un-harvestable following 75 mm rain on 1–7 June 2016.
- This experiment (despite not being harvested) confirmed district field crop observations that an earlier sowing date (on or about 1 December) is preferable to avoid wet weather at harvest if longer season lines, such as Moonbi⁽ᴰ, are to achieve their expected higher yield potential in the Macquarie Valley.

Conclusions

- Under fully irrigated conditions on a grey vertosol in the Macquarie Valley, soybean yield potential ranged from a low of 1.01 t/ha up to a high of 2.94 t/ha across two years of harvested variety evaluation experiments (third season not harvested).
- Under full irrigation scheduling (100% allocation) in the Macquarie Valley, Moonbi⁽ᴰ (released 2010) is recommended as the preferred soybean variety for high yield potential, maturity adaptation, excellent grain quality to meet human consumption markets, and

resistance to powdery mildew if maturity is delayed until late autumn. Early season sowing (on or about 1 December) is recommended for this variety to achieve its yield potential.

- Under partial irrigation scheduling (reduced allocations), later sowing window opportunities or for dryland situations, the Djakal soybean variety would be more suited with consistent high yields, earlier maturity, lodging resistance due to shorter height and reduced biomass, and an ability to achieve human consumption quality under less favourable growing conditions.
- In the Macquarie Valley region, delayed sowing of a soybean crop can increase the likelihood of delayed maturity running into prolonged periods of wet autumn weather at harvest time – the 2015–16 experiment could not be harvested for this reason.

Acknowledgements

These experiments were part of the project *Northern pulse agronomy initiative – NSW* (DAN00171) with joint investment by NSW DPI and GRDC. Technical assistance with field work provided by Scott Richards, Jayne Jenkins, Liz Jenkins and Joanna Wallace (all NSW DPI, Trangie) is gratefully acknowledged. Gavin Melville (NSW DPI biometrician) provided statistical analysis and support for these experiments. Kelvin Appleyard and supporting farm staff at Trangie ARC are also acknowledged for providing experiment sites, and preparing and managing fields.

Evaluation of new mungbean varieties for the Macquarie Valley – Trangie Agricultural Research Centre, 2013–2016

Leigh Jenkins
NSW DPI, Trangie ARC

Key findings

- Mungbean yield potential ranged from a low of 0.81 t/ha up to a high of 2.70 t/ha in three years of irrigated variety evaluation experiments at Trangie in the Macquarie Valley.
- Jade_AU⁽ᵈ⁾ (released 2013) is the recommended variety for Macquarie Valley mungbean growers with the highest yield potential, largest seed size (an important quality attribute for marketing) and best disease tolerance package. Crystal⁽ᵈ⁾ would be an adequate second-best option based on yield and potential seed size.
- Niche mungbean varieties such as Regur (black gram type), and the two small-seeded lines Celera II⁽ᵈ⁾ and Green Diamond⁽ᵈ⁾, would have to command a substantial premium for their respective seed quality attributes to compensate for the poorer yield potential demonstrated in these experiments.

Introduction

The Northern Pulse Agronomy Initiative (NPAI) was established as a joint project between NSW DPI and GRDC in 2013. A key outcome from this project is developing management packages that lead to greater adoption, productivity and profitability of both winter and summer pulses in the northern grains region of NSW. Identifying and understanding the constraints that limit potential productivity will lead to more reliable pulse crops, allowing seasonal yield potential and quality characteristics to be achieved.

In recent years, mungbean has regained popularity in northern NSW as a short season, summer opportunity crop for three reasons:

1. reduced irrigation allocations (limiting cotton production)
2. the release of new mungbean varieties with improved yield and disease resistance
3. higher prices.

This has led to improved profitability of mungbean as a stand-alone crop, in addition to its rotational benefits as a pulse crop. However, adoption in the Macquarie Valley (central west NSW) has been limited by a lack of current agronomic information regarding best management practices for new varieties.

Through the support of the NPAI project, NSW DPI conducted mungbean variety evaluation experiments (in collaboration with more variety-specific agronomy experiments) at Trangie Agricultural Research Centre (Trangie ARC) for three consecutive summer seasons (2013–14, 2014–15 and 2015–16), to assess how effective new mungbean varieties for the Macquarie Valley were under irrigated conditions.

Site details

Location	All three experiments were conducted at Trangie ARC.
Soil type	Grey vertosol.
Irrigation	Full flood irrigation schedule, including pre-irrigation before planting and in-crop irrigation as required throughout the growing season.
Row spacing	These experiments were all planted on standard row spacing of 33 cm.
Plant population	Sowing rates were adjusted for each variety's individual seed size to achieve a consistent plant density of 35 plants/m^2.
Experiment design	Randomised complete block design with three replications.

Treatments

Table 1. Mungbean variety trial treatment list.

Treatment	2013–14 season	2014–15 season	2015–16 season
Varieties	Berken Crystal Green Diamond Jade_AU M09246 (Celera II) Regur Satin II	Berken Celera II Crystal Green Diamond Jade_AU M010047 M011057 Regur Satin II	Berken Celera II Crystal Green Diamond Jade_AU M010047 M011057 Regur Satin II
Sowing date	17 Dec 2013	16 Dec 2014	17 Dec 2015
Harvest date (days after sowing – DAS)	17 April 2014 (121 DAS)	15 April 2015 (120 DAS)	22 March 2016 (96 DAS)

Results

2013–14 season

- The mean yield in 2013–14 was 1.75 t/ha (1.19–2.19 t/ha).
- The three newly released varieties Jade_AU⟨PBR⟩ (2013), Crystal⟨PBR⟩ (2008) and Satin II⟨PBR⟩ (2008) all had yields >2.0 t/ha and were significantly higher yielding than the other four varieties.
- The experimental line M09246 was subsequently released in 2014 as Celera II⟨PBR⟩ as a replacement for Green Diamond⟨PBR⟩; both varieties target the small-seeded niche market, but did not achieve the yield potential of larger seeded varieties.
- Regur is a variety of black gram with dull grey-coloured seed targeting quality export markets in Japan; but in this experiment was the lowest yielding variety.
- The mean seed size (measured as 100-seed weight) was 5.77 g (3.54–7.23 g).
- Crystal⟨PBR⟩ (7.23 g) had a significantly larger seed size than all other varieties except its replacement Jade_AU⟨PBR⟩ (6.83 g).
- Both Green Diamond⟨PBR⟩ and its replacement line M09246 (now Celera II⟨PBR⟩) had significantly smaller seed size <4.0 g which, in part, contributed to their lower yield potential.

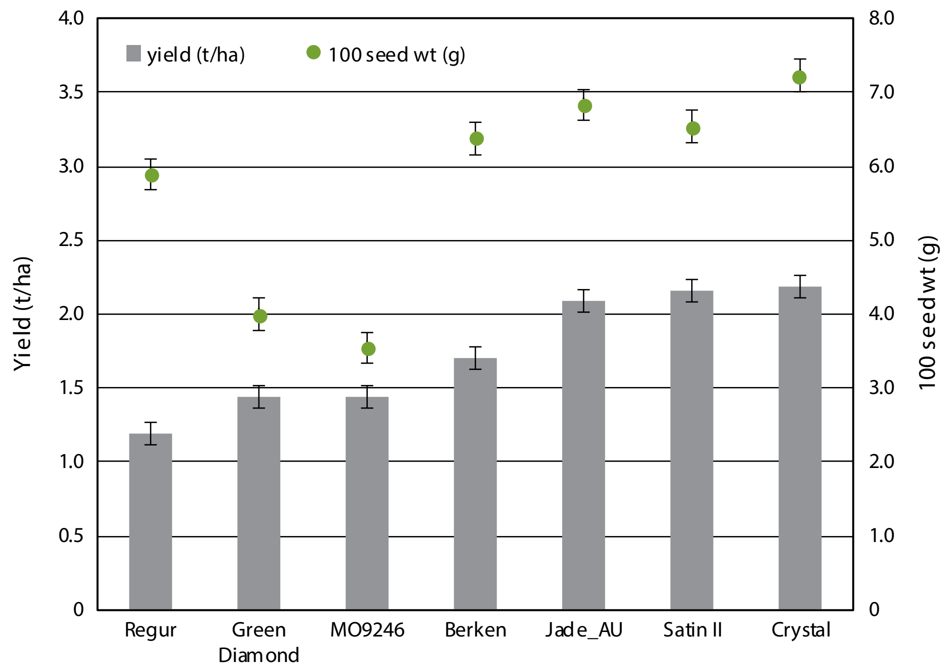

Figure 1. Grain yield (t/ha) and 100-seed weight (g) for seven varieties of mungbean at Trangie ARC, 2013–2014 season. l.s.d. yield (P<0.001) = 0.15 t/ha; l.s.d. 100-SW (P<0.001) = 0.42 g.

2014–15 season

- The mean yield in 2014–15 was 2.05 t/ha (0.97–2.70 t/ha).
- The three newly released varieties, Jade_AU⁽ᵇ⁾ (2013), Crystal⁽ᵇ⁾ (2008) and Satin II⁽ᵇ⁾ (2008), all had yields >2.6 t/ha and were significantly higher yielding than the other six varieties.
- The small seeded variety Celera II⁽ᵇ⁾ (Green Diamond⁽ᵇ⁾ replacement) was significantly lower yielding than all other varieties in this experiment; whilst Green Diamond⁽ᵇ⁾ was again in the lowest three rankings for yield.
- Regur (black gram variety) achieved a quite respectable yield of 2.1 t/ha in this season's experiment compared with the previous season. Note that Regur was harvested separately three weeks later than the other eight varieties (6 May) due to very late maturity.
- The mean seed size (measured as 100-seed weight) was 6.92 g (4.20–8.62 g), hence the higher yield potential for this season was matched by larger seed size compared with the previous 2013–14 season.
- The two experimental lines MO10047 and MO11057 had significantly larger seed than all other lines (>8.6 g); followed by Crystal⁽ᵇ⁾ and Jade_AU⁽ᵇ⁾ (>7.8 g), Satin II⁽ᵇ⁾ and Berken (>7.2 g).
- Both Green Diamond⁽ᵇ⁾ and its replacement line Celera II⁽ᵇ⁾ had significantly smaller seed size < 4.3 g, which again contributed to lower yield potential as per the previous season.
- Flowering dates were recorded for the 2014–15 experiment with Celera II⁽ᵇ⁾ at F50% on 28 January (43 DAS) and all eight other varieties at F50% on 2 February (48 DAS) (data not shown).
- Peak maturity biomass was measured by quadrant cuts on 30 March (two weeks pre-harvest) with a mean biomass of 2900 kg/ha for all varieties. Crystal⁽ᵇ⁾ had the highest mean biomass (3755 kg/ha), Celera II⁽ᵇ⁾ had lowest mean biomass (2130 kg/ha); hence there was a reasonable correlation (R^2 = 0.62) between peak maturity biomass and harvested yield (data not shown).

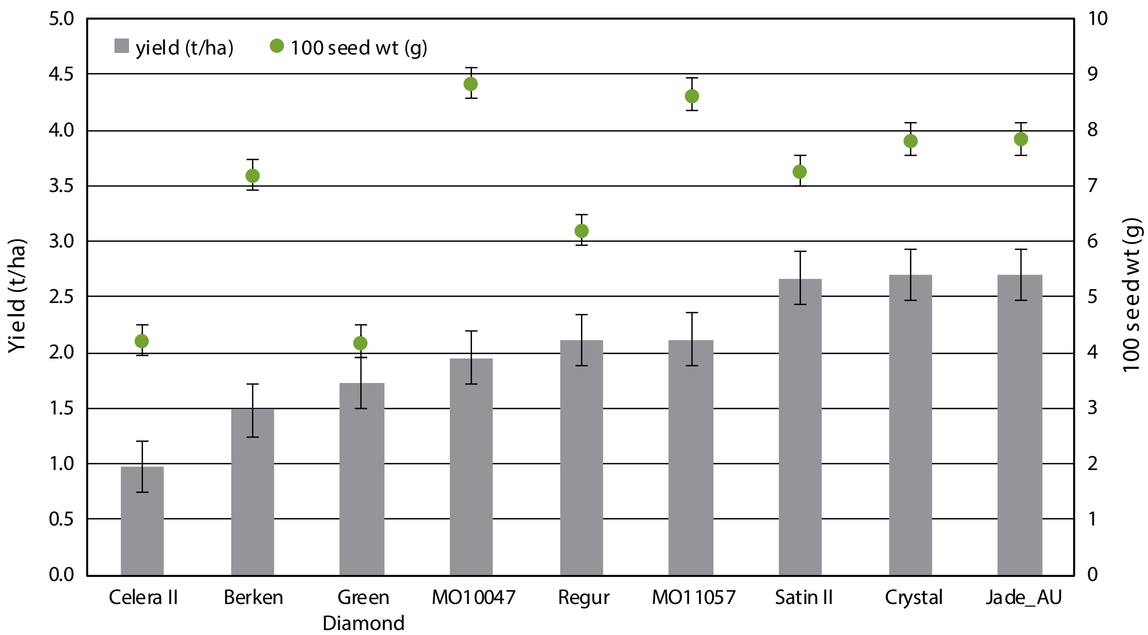

Figure 2. Grain yield (t/ha) and 100-seed weight (g) for nine varieties of mungbean at Trangie ARC, 2014–2015 season. l.s.d. yield (*P*<0.001) = 0.47 t/ha; l.s.d. 100-SW (*P*<0.001) = 0.57 g

2015–16 season

- The mean yield in 2015–16 was 1.01 t/ha (0.81–1.26 t/ha).
- Jade_AU⁽ᵈ⁾ and Berken had the highest mean yields at 1.26 t/ha and 1.20 t/ha respectively, followed by Satin II⁽ᵈ⁾. All six other varieties, including Crystal⁽ᵈ⁾ and Regur, yielded <1.0 t/ha and were not significantly different from each other, except for the experimental line MO11057, which produced significantly lower yields.
- The mean seed size (measured as 100-seed weight) was 5.59 g (3.30–6.78 g).
- Jade_AU⁽ᵈ⁾ had the largest seed size (6.78 g), but was not significantly different from the experimental lines MO10047 or MO11057, plus Crystal⁽ᵈ⁾, which all had a seed size of >6.5 g. Satin II⁽ᵈ⁾ had a seed size >6.0 g.
- Celera II⁽ᵈ⁾ and Green Diamond⁽ᵈ⁾ had significantly smaller seed (<3.5 g) than all other varieties.
- Flowering dates were recorded for the 2015–16 experiment with Celera II⁽ᵈ⁾ at F50% on 3 February (48 DAS); Berken, Jade_AU⁽ᵈ⁾ and Satin II⁽ᵈ⁾ on 9 February (54 DAS); Crystal⁽ᵈ⁾ on 10 February (55 DAS); and Green Diamond⁽ᵈ⁾ and Regur on 12 February (57 DAS).
- Peak maturity biomass was measured by quadrant cuts on 9 March (two weeks pre-harvest) with a mean biomass of 6360 kg/ha for all varieties. Jade_AU⁽ᵈ⁾ and Crystal⁽ᵈ⁾ had the highest mean biomass of the named varieties (both >7000 kg/ha), but otherwise in this experiment there was a very poor correlation (data not shown) between peak maturity biomass and harvested yield.

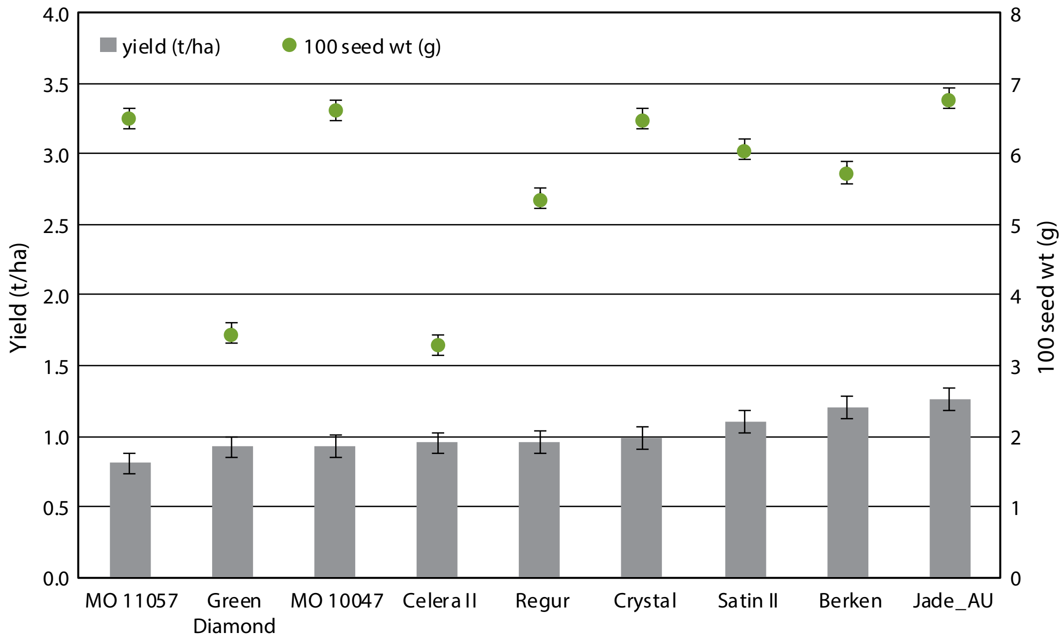

Figure 3. Grain yield (t/ha) and 100-seed weight (g) for nine varieties of mungbean at Trangie ARC, 2015–2016 season. l.s.d. yield ($P<0.001$) = 0.15 t/ha; l.s.d. 100-SW ($P<0.001$) = 0.30 g.

Conclusions

- Under fully irrigated conditions on a grey vertosol in the Macquarie Valley, mungbean yield potential ranged from a low of 0.81 t/ha up to a high of 2.70 t/ha across three years of variety evaluation experiments.
- The new mungbean variety Jade_AU⁽ᵈ⁾ (released 2013), remains the preferred variety for Macquarie Valley mungbean growers with the highest yield potential, largest seed size (an important quality attribute for marketing) and best disease tolerance package.
- Crystal⁽ᵈ⁾ (released 2008), would be an adequate second-best option, based on yield and seed size potential, if Jade_AU⁽ᵈ⁾ seed cannot be sourced.

- Satin II⊕ (released 2008), achieved a yield potential in the top three rankings (with Jade_AU⊕ and Crystal⊕) through three years of experiments; however, growers should note there is a limited market size for this dull-seeded variety.
- Niche mungbean varieties such as Regur (black gram type), and the two small-seeded lines Celera II⊕ and Green Diamond⊕, would have to command a substantial premium for their respective seed quality attributes to compensate for the poorer yield potential demonstrated in these three experiments.

Acknowledgements

These experiments were part of the project *Northern pulse agronomy initiative – NSW* (DAN00171) with joint investment by NSW DPI and GRDC. Technical assistance with field work provided by Scott Richards, Jayne Jenkins, Liz Jenkins and Joanna Wallace (all NSW DPI, Trangie) is gratefully acknowledged. Gavin Melville (NSW DPI biometrician) provided statistical analysis and support for these experiments. Kelvin Appleyard and supporting farm staff at Trangie ARC are also acknowledged for providing experiment sites, and preparation and in-crop management of fields.

New Australian soybean variety Richmond⁽ᵇ outperforms traditional varieties, Asgrow A6785 and Soya 791

Natalie Moore[1], Sam Blanch[1], Nathan Ensbey[1], Andrew James[2] and Stephen Morris[3]
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[3]NSW DPI, Wollongbar

Agronomy

Key findings

- Richmond⁽ᵇ produced an average yield 7% higher than Soya 791 in advanced variety evaluations at early sowing dates (first week in December) over six seasons.
- Richmond⁽ᵇ produced an average yield 7.7% higher than Asgrow A6785 in advanced variety evaluations at late sowing dates (mid January) over eight seasons.
- In on-farm experiments, Richmond⁽ᵇ yielded 16% higher than Soya 791 in a wide-row system on the northern slopes, and 7% higher than Asgrow A6785 in a narrow-row coastal system.
- In addition to higher yield potential, Richmond⁽ᵇ is tolerant to lodging and pre-harvest weather damage, has clean leaf drop, large seed size and high protein, and is resistant to powdery mildew. This combination of traits provides greater crop security and a full range of market options for growers, and high quality grain for buyers and processors.

Introduction

The Australian Soybean Breeding Program develops varieties for diverse production environments across a 3000 km range from the Atherton Tablelands in far north Queensland (Latitude 17.2661°S, Longitude 145.4859°E) to the Riverina in southern New South Wales (Latitude 29.7503°S, Longitude 120.5530°E).

The program focuses on strategies to broaden the range of adaptation of new cultivars (James & Lawn, 2011), and to complete the transition from traditional dark hilum types that supply lower-value crushing markets to clear hilum types with the grain qualities required for human consumption markets. Advances in yield, disease resistance and other agronomic traits are also targeted.

Primarily, a single seed descent method is used to advance populations to the F4 level of inbreeding. Varieties from the Australian Soybean Breeding Program are not genetically modified (non-GMO). Regional evaluation and selection for environmental adaptation and specific regional traits is carried out across a wide range of environments in the target production regions. Typically, new soybean lines progress through stages of small-scale replicated evaluations for 6–8 seasons, with processors conducting small-scale grain evaluations. Advanced lines then complete evaluation in replicated on-farm experiments before commercial licensing and release.

This paper summarises data from multi-season replicated evaluations and on-farm experiments of Richmond⁽ᵇ, a new variety for production in northern New South Wales.

Site details

Experiment 1. Multi-season advanced variety evaluation (Stage 2–3 equivalent)

Location	NSW DPI, Grafton
Soil type and nutrition	The experiment site was located on deep, well-drained river terrace soil with an acidic pH (4.9_{Ca}). The acidic pH of this site was specifically chosen as it enables soybean varieties to be screened for tolerance to acidic soils and manganese toxicity, which is associated with acidic cropping soils. Nutrient application for soybean evaluations at this site was based on soil test results. Potassium and sulfur were applied before sowing by broadcasting sulfate of potash at a rate of 130 kg/ha.

Phosphorus, molybdenum and calcium were applied as single Mo-Super phosphate fertiliser over the row at planting at 280 kg/ha. No other starter fertiliser was used. Group H soybean inoculant (formerly as the Becker Underwood® liquid and recently as a peat formulation) was used to inoculate all seed every season.

Rainfall

Average in-crop rainfall for this site for the seasons reported in this paper was 533 mm for early-sown experiments and 436 mm for late sown experiments.

Design and data analysis

Soybean evaluation experiments were designed and analysed by a biometrician using the principles of spatial analysis of field experiments outlined in Gilmour, Cullis & Verbyla, (1997). Estimates of pre-harvest and harvest traits for each variety were obtained after accounting for natural and extraneous sources of variation Gilmour, Cullis & Verbyla, (1997). Various commercial varieties were included in all experiments as benchmarks for particular traits. Each experiment was comprised of four replicates, which were used to collect data on all traits, except for weathering tolerance, which was replicated nine times. Weathering tolerance was measured by the amount of weather-damaged grain after a period of exposure to simulated rainfall (usually five days and two hours at temperatures of 19–22 °C) in a weathering facility. Data analysis was undertaken using R for windows and comparisons made via a general mixed linear model approach using the asreml package (Butler et al., 2009; R Development Core Team 2016).

Sowing date

Early variety evaluation experiments were sown between 2 December and 5 December each year. Late variety evaluation experiments were sown between the 11 January and 13 January each year.

Plant population

An established plant population of 360 000 plants/ha was used with a row spacing of 30 cm.

Weed management

Weed management typically included a post-plant pre-emergent application of glyphosate at a rate of 1 L/ha with Dual Gold® (960 g/L S-metolachlor) at 1 L/ha. Spinnaker® 700 WDG (700 g/kg imazethapyr) was applied 2–3 weeks after emergence at 100 g/ha. Verdict® 520 (520 g/L haloxyfop present as the haloxyfop-R methyl ester) was only applied at 150 mL/ha if required before canopy closure.

Insect management

Bug checking was conducted at regular intervals and an integrated pest management approach followed to conserve as many beneficial insects as possible. The following insecticides were used if required (note that not all insecticides were applied to all experiments in all seasons):

- ViVUS MAX® (5 × 109 nucleopolyhedro virus of *Helicoverpa armigera* per mL) at 150 mL/ha to control *Helicoverpa*
- Dipel SC® (*Bacillus thuringiensis* subsp *kurstaki* ABTS-351) at 4 L/ha to control soybean looper
- Pirimor WG® (pirimicarb 500 g/kg) at 500 g/ha to control only widespread or severe infestations of soybean aphid
- Wizard 18® (abamectin 18 g/L) at 300 mL/ha to control mites
- Altacor® (350 g/kg chlorantraniliprole) at 70 g/ha to control soybean stemfly
- Decis Options® (deltamethrin 27.5 g/L) at 2.5 L/ha to control pod-sucking bugs such as green vegetable bug, red-banded shield bug and *Riptortis*.

Disease management	If required, Folicur® 430SC (430 g/L tebuconazol) was applied at 245 mL/ha to manage soybean leaf rust.
Harvest date	The abovementioned sowing dates typically resulted in the harvest of early-sown variety experiments in the first half of April and late sown experiments in the second half of April to early May.

Experiment 2. On-farm evaluation Oakwood, northern slopes NSW

Location	'Narellan', Oakwood, NSW
Co-operator	Brad Schwark
Soil type	Black self-mulching clay soil with a neutral pH (6.8–7.0).
Rainfall	The total rainfall from the beginning of December 2012 to the end of April 2013 was 420 mm.
Design and data analysis	The design consisted of a randomised block layout, with two replicates of each variety; each plot was 0.168 ha (8 m wide × 210 m long). The entire plot was harvested and weighed to determine grain yield.
Sowing date	19 December 2012
Plant population	A wide row spacing of 1 m was used in this dryland experiment, with a target plant population of 180,000 plants/ha (Figure 1).
Harvest date	April 2013

Experiment 3. On-farm evaluation Harwood, North Coast NSW

Location	Watts Lane, Harwood, North Coast NSW
Co-operator	Tim McMahon
Soil type and nutrition	The paddock consisted of riverbank alluvial soil, classified as a deep, brown clay loam. It was a dryland (rain-fed) soybean production system in rotation with sugar cane. The farmer's practice for paddock preparation was followed for this experiment, which was conventional cultivation using an offset disc, ripper and rotary hoe. DAP fertiliser was applied as per the farmer's normal practice at 57 kg/ha at planting.
Rainfall	Total in crop rainfall was 414 mm with a drier than normal period during late January and February.
Design and data analysis	The experiment was designed with two plots of each variety per replicate, with three replications running the full length of the paddock in a randomised design. Each plot was 9 m wide (three planter widths) and 340 m long, with a 1 m gap to separate each plot for ease of harvesting. The harvested area to determine grain yield was 0.306 ha for each plot.
Sowing date	7 December 2015

Plant population	Soybean was sown into flat ground as per the farmer's practice using a Duncan model 3 m combine seeder (15 cm row spacing). Trimble GPS guidance was used for planting. The targeted plant population was 320,000 plants/ha, which was achieved with an even plant population established across the site.
Weed management	Dual Gold® (960 g/L S-metolachlor) at 1.4 L/ha was applied post-planting pre-emergence and Spinnaker® 700 WDG (700 g/kg imazethapyr) at 100 g/ha was applied before canopy closure.
Insect management	Bug checking was conducted at regular intervals to determine the identity of pest and beneficial insects in the crop. In-crop insect management consisted of one application of: • ViVus MAX® (5 × 109 nucleopolyhedro virus of *Helicoverpa armigera*/mL) at 150 mL/ha to control *Helicoverpa* early in the crop cycle • Dipel® SC (*Bacillus thuringiensis* subsp. *kurstaki* ABTS-351) at 4 L/ha to control soybean looper • Steward® EC via spray (150 g/L Indoxacarb) at 400 mL/ha to control an outbreak of *Helicoverpa* later in the crop cycle.
Disease management	None required.
Harvest date	April 2016

Treatments

Experiment 1. Varieties

Richmond$^{\phi}$, Moonbi$^{\phi}$, Zeus, Soya 791

Experiment 2. Varieties

Richmond$^{\phi}$, Moonbi$^{\phi}$, Soya791

Experiment 3. Varieties

Richmond$^{\phi}$, Asgrow A6785

Results

Experiment 1. Multi-season advanced variety evaluation experiments (S2–3 equivalent) at early and late sowing dates

Average results for yield and important plant characteristics are collated in tables 1 and 2 for the early (first week of December) and late (mid January) sowing windows respectively. Lodging scores are provided for early-sown experiments only, as lodging is not usually severe in later-sown soybean crops. Differences between averages that exceed the estimate of least significant difference (l.s.d.) can be regarded as statistically important at the 5% critical value (P<0.05).

Table 1. Analysed data summary of soybean variety evaluations, early-sowing window (first week December) for six seasons between 2008–09 and 2014–15, NSW DPI Grafton.

Variety	Grain yield (t/ha)[◊]	Grain protein (% dry matter)	Weathering tolerance (% unweathered grain)	Seed size (g/100 seed)[◊]	Seed size (seeds/kg)	Maturity (P95/R8)[§]	Plant height (cm)	Lodging[¤]
Richmond[Ⓓ]	4.6	42.3	73.7	22.1	4532	131	85	1.5
Moonbi[Ⓓ]	4.1	42.6	72.5	21.8	4580	121	91	1.6
Zeus[€]	–	–	84.1	–	–	–	–	–
Soya 791[¥]	4.3	41.8	53.2	19.2	5217	139	99	2.9
l.s.d.	0.4	1.3	8.6	1.4	–	1.7	7.0	0.7

[€] Zeus is included as the benchmark for highest weathering tolerance in all experiments
[¥] Soya 791 is included as the benchmark for lowest weathering tolerance in early sown experiments
[◊] at 12% moisture
[§] days after sowing to reach harvest maturity
[¤] lodging score 1 = nil up to 5 = severe

Table 2. Analysed data summary of soybean variety evaluations, late sowing window (mid January) for eight seasons between 2006–07 and 2015–16, NSW DPI Grafton.

Variety	Grain yield (t/ha)[◊]	Grain protein (% dry matter)	Weathering tolerance (% unweathered grain)	Seed size (g/100 seed)[◊]	Seed size (seeds/kg)	Maturity (P95/R8)[§]	Plant height (cm)
Richmond[Ⓓ]	4.3	42.4	77.5	22.0	4540	118	59
Bunya[Ⓓ]	4.1	40.4	73.0	24.8	4040	116	71
Hayman[Ⓓ]	4.1	43.8	79.6	23.5	4260	122	94
Asgrow A6785	4.0	39.4	77.7	15.3	6540	111	77
Zeus[€]	–	–	86.4	–	–	–	–
Warrigal[¥]	3.9	41.0	57.9	19.7	5070	118	87
l.s.d.	0.35	1.1	6.4	1.0		3.2	7.7

[€] Zeus is included as the benchmark for highest weathering tolerance in all experiments
[¥] Warrigal is included as the benchmark for lowest weathering tolerance in late sown experiments
[◊] at 12% moisture
[§] days after sowing to reach harvest maturity

Experiment 2. On-farm evaluation,Oakwood, northern slopes NSW

Richmond[Ⓓ] produced an additional 0.42 t/ha or 16% more grain than Soya 791, with similar days to maturity, less lodging and cleaner leaf drop, which improved the ease of harvest according to the grower. At the time this experiment was conducted, the End Point Royalty (EPR) for new soybean varieties was $12/t. In 2017 it was reduced to $6/t. Both rates are used in the economic comparison for the experiment results presented in Table 3. A conservative grain price of $500/t is used.

Table 3. Grain yield and economic comparison of a soybean variety evaluation on-farm experiment conducted at Oakwood, NSW, in summer 2012-2013. Data represents averages of two replicates.

Variety	Grain yield (t/ha)	Yield increase compared with Soya 791 (%)	Gross income from grain less EPR of $12/t ($/ha)	Gross income from grain less EPR of $6/t ($/ha)
Richmond[Ⓓ]	3.07	16	1498	1517
Moonbi[Ⓓ]	2.92	10	1425	1442
Soya 791	2.65	–	1325	1325

Note: Grain price = $500/t. EPR deductions are applied to Richmond[Ⓓ] and Moonbi[Ⓓ] only.

Figure 1. Richmond[PBR] (3.07 t/ha) out-yielded Soya 791 (2.65 t/ha) by 16% in this wide-row spacing (1 m) dryland experiment at Brad Schwark's property near Oakwood on the northern slopes of NSW.

Experiment 3. On-farm evaluation Harwood, North Coast NSW

Richmond[PBR] produced an additional 0.27 t/ha or 7% more grain than Asgrow A6785, with similar days to maturity, much less lodging and cleaner leaf drop than A6785. Tolerance to lodging and pre-harvest weathering are important traits to avoid fungal diseases and maintain grain quality in coastal production environments. Two rates are used for EPR in the economic comparison of the experiment results due to a recent change in pricing structure (Table 4). A premium edible grade price of $612/t is used.

Table 4. Grain yield and economic comparison of an on-farm soybean variety evaluation experiment conducted near Harwood, NSW, in summer 2015–2016. Data represent averages of three replicates.

Variety	Grain yield (t/ha)	Yield increase compared with A6785 (%)	Peak shoot biomass (t dry matter/ha)	Gross income from grain less EPR of $12/t ($/ha)	Gross income from grain less EPR of $6/t ($/ha)
Richmond[PBR]	4.19	7	8.02	2514	2539
Asgrow A6785	3.92	–	9.39	2399	2399

Note: Grain price = $612/t which is premium edible grade. EPR deduction is applied to Richmond[PBR] only.

Conclusions

The Australian soybean variety Richmond[PBR] produces large grain (22 g/100 seed) with a clear hilum and high levels of protein (42% dry matter), which is suitable for all markets including human consumption and export. The traditional variety, Asgrow A6785, has small grain (<16 g/100 seed) with a brown hilum and protein levels less than 40%, which limits the range of markets to which it is suited. The traditional variety, Soya 791, has average sized grain

(19 g/100 seed) with a light brown hilum and high levels of protein (42%). Both A6785 and Soya 791 are prone to excessive vegetative growth, especially at an early sowing date. However, this is not necessarily converted into grain yield as demonstrated in the on-farm experiment at Harwood.

Richmond⁽ᵈ⁾ is superior to A6785 and Soya 791 in terms of grain yield, tolerance to lodging, tolerance to pre-harvest weathering and clean leaf drop. Richmond⁽ᵈ⁾ offers a summer legume option with high yield and high grain quality for early, mid or late sowing windows in northern New South Wales. The variety's performance was not adversely affected by the range of soil types and farming systems reported in this paper; it was superior to A6785 and Soya 791 in all situations. Richmond⁽ᵈ⁾ is resistant to powdery mildew. This package of traits represents a significant advance in soybean varieties for the North Coast, Tablelands, Northern Slopes and Liverpool Plains production regions of northern New South Wales.

The results of the on-farm experiment of Richmond⁽ᵈ⁾ versus Soya 791 in a wide spacing, single row system at Oakwood demonstrates the variety's ability to compensate for wide rows and the associated lower plant populations in dryland systems. Row spacing and plant population interactions of new soybean and mungbean varieties are being investigated in the current NSW DPI–GRDC project DAN00171.

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Sunflower configuration × population × hybrid – Gurley 2015–16

Loretta Serafin, Mark Hellyer and Peter Perfrement
NSW DPI, Tamworth

Key findings

- Sunflower yields were very low at this site in 2015–16, averaging 0.56 t/ha.
- Plant population affected plant measurements, with larger head diameters and 1000 grain weights resulting from lower populations.
- Hybrid selection also affected plant measurements. Ausistripe 14 had the longest arc length but the smallest head diameter. Ausigold 4 and Ausigold 62 had very similar plant characteristics.

Introduction

Optimising sunflower performance relies on being able to match a hybrid with the growing environment and ensuring that the most suitable agronomic management is provided. Suitable crop agronomy involves using the most appropriate row configuration and plant population as well as ensuring adequate nutrition, disease and insect management.

This experiment and others conducted in this series were designed to provide recommendations for growers and advisors to support decisions on optimal row configuration, plant population and hybrids for sunflower production in the north-western and Liverpool Plains regions of NSW. These two environments are the primary sunflower growing regions in northern NSW.

Site details

Location	'Kyntyre', Gurley
Co-operator	Doug Clark
Soil type and nutrition	The site was soil cored before sowing to determine starting nutrition (Table 1). Starting nitrogen (N) levels were 112 kg N/ha to a depth of 1.2 m.
Starting soil water and rainfall	The site was soil cored before sowing and found to have 103 mm of plant available water (PAW) to a depth of 1.2 m. A total of 284.5 mm of in-crop rainfall was recorded at the site (Table 2). This was largely received as one large fall of over 50 mm in mid-November and another large fall of 68.5 mm in early January. The intensity of these summer storm events meant the rainfall was not effective, as a large amount of rain was lost as runoff.
Sowing date	9 September 2015
Fertiliser	42 kg/ha Granulock Z applied at sowing
Harvest date	23 February 2016

Treatments

Hybrids (3)

Ausigold 4
Ausigold 62
Ausistripe 14

Row configuration (3)

Solid 100 cm
Single skip (100 cm)
Superwide (150 cm)

Plant population (3)

15,000 plants/ha
25,000 plants/ha
35,000 plants/ha

Table 1. Soil chemical characteristics.

Characteristic	Depth (cm)				
	0–10	10–30	30–60	60–90	90–120
pH (1:5 $CaCl_2$)	6.1	7.0	7.8	7.9	8.0
Nitrate nitrogen (mg/kg)	6.0	8.0	11.0	11.0	2.0
Sulfur (mg/kg)	2.7	3.1	18.8	131.7	195.7
Phosphorus (Colwell) (mg/kg)	16.0	4.0	2.0	<2.0	3.0
Organic carbon (OC) (%)	0.49	0.43	0.34	0.28	0.12

Table 2. In-crop rainfall at 'Kyntyre', Gurley in 2015–16.

Month	September	October	November	December	January	February
Rainfall (mm)	0	17	93.5	1.5	68.5	104

Results

Establishment

Plant establishment was slightly better than the targeted populations for all populations (Table 3). There was no difference in the establishment between hybrids.

Table 3. Target versus actual plant populations established, Gurley 2015–16.

Target plant population (plants/ha)	Actual established population (plants/ha)
15,000	20,680
25,000	28,120
35,000	44,260

Plant height

Five plants in each plot were measured for height, taken from ground level up to the point of attachment at the back of the head. There was no difference in plant height between the hybrids, plant populations or row configurations (data not shown). The average plant height in the experiment was 152 cm.

Head diameter and arc length

The head diameter and arc length of five plants in each plot was measured. Head diameter was measured across the back of the head and arc length across the front face of the head.

Plant population and hybrid selection both caused significant differences in both parameters.

Head diameters averaged 11.8 cm, indicating that yields were likely to be reasonably low. Head diameters decreased as the plant populations increased, with significant differences between each plant population (data not shown). There were also differences between the hybrids. Ausigold 62 and Ausigold 4 were not different from each other with head diameters of 13.0 cm and 12.3 cm respectively, but both were larger than Ausistripe 14 at 10.2 cm.

Head arc lengths decreased as plant populations increased. In contrast to the head diameters, Ausistripe 14 had the longest arc length at 19.7 cm, followed by Ausigold 4 at 18.3 cm and Ausigold 62 at 17.5 cm. As Ausistripe 14 is a confectionary hybrid, the seeds are typically longer, resulting in a more rounded head shape.

Grain yield

Sunflower yields were very low at this site in 2015–16 with an average of 0.56 t/ha. The coefficient of variation for grain yield was very high and, as such, no other grain yield results can be reported as the level of variability in the data was too high.

Grain quality

Sub samples from each plot were collected at harvest and analysed for 1000 grain weight and test weight. Plant population and hybrid selection caused significant differences in 1000 grain weight. The 1000 grain weight decreased as plant population increased (data not shown).

Ausistripe 14 had the highest 1000 grain weight and test weight, although its test weight was not significantly different from Ausigold 62 (Table 4).

Oil contents were not available at the time of writing.

Table 4. Hybrid performance at 'Kyntyre' – Gurley 2015–16.

Hybrid	1000 grain weight (g)	Test weight (kg/hL)
Ausigold 4	41.0	35.8
Ausigold 62	38.1	38.3
Ausistripe 14	44.4	39.7
l.s.d ($P = 0.05\%$)	1.26	3.09

Conclusions

Sunflower grain yields at this site in 2015–16 were very low as a result of the dry growing conditions, averaging only 0.56 t/ha and quite variable across the site. Varying row configuration did not affect either plant or grain parameters at this site under these low-yielding conditions. Varying plant populations and hybrids had the greatest effect on plant structures such as head diameter and head arc length. Larger head sizes and higher 1000 grain weights resulted from having lower plant populations under the dry conditions experienced at this site in 2015–16.

Acknowledgements

This experiment was part of the project *Tactical agronomy for selected crops in the northern region* (*safflower, linseed, sunflower*) (DAN00197), with joint investment by NSW DPI and GRDC. Technical assistance provided by Delphi Ramsden, Angus Hombsch, Alice Bowler and Bronwyn Brennan (NSW DPI) is gratefully acknowledged. Thanks to Doug Clark, 'Kyntyre', Gurley for hosting the experiment.

Contribution of leaves to the yield of sunflowers – Gurley 2015–16

Loretta Serafin, Mark Hellyer and Peter Perfrement
NSW DPI, Tamworth

Agronomy

Key findings

- Sunflower yields were very low at this site in 2015–16, averaging 0.24 t/ha, and overall variability was very high.
- The total removal of leaves at the budding stage had the largest impact on plant structures; plant height, head diameter and arc length.

Introduction

Sunflowers are generally considered a minor crop in the northern grains region. However, they play an important role in providing a broadleaf summer crop rotation option. An individual sunflower plant produces on average between 2000–6,000 cm^2 of leaf area, which drives yield and oil content.

Identifying which leaves contribute most towards yield and oil content helps growers make decisions about disease, pest and general crop management in sunflower crops. Whether it is because the crop is infected with a disease such as powdery mildew, or has insect damage e.g. loopers, the end result is a need for growers and advisors to know where and when to spend money in crop protection to achieve the best economic return on investment of maintaining green leaf area.

Site details

Location	'Kyntyre', Gurley
Co-operator	Doug Clark
Soil nutrition	The site was soil cored before sowing to determine starting nutrition (Table 1). Starting nitrogen levels were found to be 112 kg N/ha to 1.2 m deep.
Starting soil water and rainfall	The site was soil cored before sowing and found to have 103 mm of plant available water (PAW) to 1.2 m deep. A total of 284.5 mm of in-crop rainfall was recorded at the experiment site (Table 2). This was largely received as one large fall of over 50 mm in mid-November and another large fall of 68.5 mm in early January. The intensity of these summer storm events meant they were not as effective as they could have been if these volumes had been received over a more prolonged period.
Sowing date	9 September 2015
Fertiliser	42 kg/ha Granulock Z applied at sowing
Hybrid	Ausigold 62
Harvest date	23 February 2016

Table 1. Soil chemical characteristics.

Characteristic	Depth (cm)				
	0–10	10–30	30–60	60–90	90–120
pH (1:5 $CaCl_2$)	6.1	7.0	7.8	7.9	8
Nitrate nitrogen (mg/kg)	6	8	11	11	2
Sulfur (mg/kg)	2.7	3.1	18.8	131.7	195.7
Phosphorus (Colwell) (mg/kg)	16	4	2	<2	3
Organic carbon (OC) (%)	0.49	0.43	0.34	0.28	0.12

Table 2. In-crop rainfall at 'Kyntyre', Gurley in 2015–16.

Month	September	October	November	December	January	February
Rainfall (mm)	0	17	94	2	69	104

Treatments

The experiment aimed to quantify the contribution of different sunflower leaves to yield and oil quality through applying 12 leaf defoliation treatments.

Defoliation treatments (12)

1. Control – no leaves removed (0/3)
2. Budding (2 cm bud) – remove all leaves (3/3)
3. Budding (2 cm bud) – remove top 10 leaves (1/3)
4. Budding (2 cm bud) – remove top 20 leaves (2/3)
5. Budding (2 cm bud) – remove bottom 10 leaves (1/3)
6. Start of flowering (R5.1) – remove top 10 leaves (1/3)
7. Start of flowering (R5.1) – remove top 20 leaves (2/3)
8. Start of flowering (R5.1) – remove all leaves (3/3)
9. Start of flowering (R5.1) – remove bottom 10 leaves (1/3)
10. Flowering Complete (R6.1) – remove top 10 leaves (1/3)
11. Flowering Complete (R6.1) – remove top 20 leaves (2/3)
12. Flowering Complete (R6.1) – remove all leaves (3/3)

Treatments were applied by cutting off the leaves using secateurs, but leaving the leaf axil intact. Treatments were applied on:

Budding cuts – 3 and 4 November

Start of flowering (R 5.1) – 25 November

Flowering Complete (R6.1) – 7 and 8 December

Results

Plant height

Five plants in each plot were measured for height before harvest – from ground level up to the point of attachment at the back of the head. The average plant height in the experiment was 118.7 cm. The removal of all leaves at the budding stage resulted in plants with around half the height of those without leaves removed (Table 3). No other treatment affected plant height.

Head diameter and arc length

Five plants in each plot had head diameter and arc length measured before harvest. Head diameter was measured across the back of the head and arc length across the front face of the head. The average head diameter was 9.1 cm, which illustrates the likely low grain yields from such a small-sized head.

There were significant treatment differences based on defoliation (Table 3). The control, budding top 1/3, budding bottom 1/3 and start of flowering top 2/3 treatments had the largest head diameters. The total loss of leaves at the budding stage resulted in the smallest head diameter at 1.5 cm.

The average arc length was 12.1 cm and there were significant differences between defoliation treatments. Removing all leaves at budding had the largest impact on arc length, reducing it to 2.5 cm. The remaining defoliation treatments did not significantly affect arc length compared with the non-defoliated control (Table 3).

Table 3. Affect from defoliation treatments on sunflower plant structures.

Treatment	Plant height (cm)	Head diameter (cm)	Head arc length (cm)
Control – no leaves removed (0/3)	129.5	12.1	13.0
Budding – remove all leaves (3/3)	66.4	1.5	2.5
Budding – remove top 10 leaves (1/3)	123.6	11.3	13.6
Budding – remove top 20 leaves (2/3)	113.9	7.9	10.5
Budding – remove bottom 10 leaves (1/3)	126.9	10.2	11.7
Start of flowering – remove top 10 leaves (1/3)	122.5	9.1	12.0
Start of flowering – remove top 20 leaves (2/3)	126.1	10.5	13.5
Start of flowering – remove all leaves (3/3)	121.4	7.5	16.1
Start of flowering – remove bottom 10 leaves (1/3)	121.0	9.7	12.5
Flowering complete – remove top 10 leaves (1/3)	126.7	9.9	13.2
Flowering complete – remove top 20 leaves (2/3)	121.9	10.0	13.2
Flowering complete – remove all leaves (3/3)	123.8	9.3	13.9
l.s.d. ($P = 0.05$)	23.49	2.04	3.50

Agronomy

Grain yield

Yield was very low at this site in 2015–16, on average 0.24 t/ha. The coefficient of variation for grain yield was very high and, as such, no other grain yield data can be reported as the level of variability was too high.

Grain quality

Sub samples from each plot were collected at harvest and analysed for 1000 grain weight and test weight. Oil contents were not available at the time of publication.

The average 1000 grain weight in the experiment was 32.0 grams. The largest impact on grain weight was obtained by removing all leaves at budding or at the start of flowering, and removing the top 20 leaves at budding, which all had the lowest 1000 grain weights (data not shown).

The average hectolitre weight in the experiment was 42.9 kg/hL, which is well above the receival standard of 32 kg/hL. The largest differences were between removing all leaves at budding, which had the high test weight of 46.4 kg/hL and removing the bottom 10 leaves at budding, which had the lowest test weight at 39.3 kg/hL (data not shown).

Conclusions

Grain yields at this site in 2015–16 were very low as a result of dry growing conditions, averaging only 0.24 t/ha and being quite variable across the site. Hence no yield data for individual defoliation treatments have been reported. Defoliation treatments had a significant effect on plant structures, namely plant height, head diameter and arc length. Totally removing leaves at the budding stage had the largest effect on plant structures.

This experiment is one of a series conducted during the 2015–2017 seasons, comparing the effect of leaf loss on crop yield and quality. These results should be considered carefully until an across-sites and -seasons analysis is completed on the entire data set.

Acknowledgements

This experiment was part of the project *Tactical agronomy for selected crops in the northern region (safflower, linseed, sunflower)* (DAN00197), with joint investment by NSW DPI and GRDC. Thanks to Nuseed and Neil Weier for supplying experiment seed. Technical assistance provided by Delphi Ramsden, Angus Hombsch, Alice Bowler and Bronwyn Brennan (NSW DPI) is gratefully acknowledged. Thanks to Doug Clark, 'Kyntyre', Gurley for hosting the experiment.

Contribution of leaves to the yield of sunflowers – Pine Ridge 2015–16

Loretta Serafin, Mark Hellyer and Peter Perfrement
NSW DPI, Tamworth

Key findings

- Sunflower grain yield averaged 1.07 t/ha at this site with the highest yields obtained from the control and the treatments where only the bottom one third (1/3) of leaves were removed.
- The total leaf removal treatments had the largest effect on yield, at worst yielding only 0.16 t/ha.
- Removing all leaves at budding or at the start of the flowering growth stages had the largest effect on plant structures.
- Total leaf removal at the end of flowering had the largest effect on 1000 grain weight and test weight.

Introduction

Sunflowers are generally considered a minor crop in the NSW northern grains region. However, they play an important role in providing a broadleaf summer crop rotation option. An individual sunflower plant produces on average between 2000–6,000 cm^2 of leaf area, which drives yield and oil content.

Identifying which leaves contribute most towards yield and oil content helps growers make decisions about disease, pest and general crop management in sunflower crops. Whether it is because the crop is infected with a disease such as powdery mildew or has insect damage e.g. loopers, the end result is a need for growers and advisors to know where and when to spend money in crop protection to achieve the best economic return on investment of maintaining green leaf area.

This experiment was one of three sunflower leaf-loss sites conducted in the 2015–16 season, with the other sites being located at Gurley and Willow Tree.

Site details

Location	'Windy Station', Pine Ridge
Co-operator	Peter Winton, Romani Pastoral Company
Soil type and nutrition	The site was soil cored before sowing to determine starting nutrition (Table 1). Starting nitrogen levels were 122 kg N/ha to 1.2 m deep.
Starting soil water and rainfall	The site was soil cored before sowing and found to have 270 mm of plant available water (PAW) to 1.2 m deep. A total of 157.5 mm of in-crop rainfall was recorded at the experiment site (Table 2).
Sowing date	18 September 2015
Fertiliser	42 kg/ha Granulock Z applied at sowing
Hybrid	Ausigold 62
Harvest date	17 February 2016

Table 1. Soil chemical characteristics.

Characteristic	Depth (cm)				
	0–10	10–30	30–60	60–90	90–120
pH (1:5 $CaCl_2$)	7.49	7.85	8.11	8.29	9.07
Nitrate nitrogen (mg/kg)	8.29	6.27	6.45	7.39	12.9
Sulfur (mg/kg)	8.1	9.2	14	26.6	18.36
Phosphorus (Colwell) (mg/kg)	53	14.8	23.9	38.2	48.7
Organic carbon (OC) (%)	2.33	2.03	1.92	1.89	1.8

Table 2. In-crop rainfall at 'Windy Station', Pine Ridge in 2015–16.

Month	September	October	November	December	January	February
Rainfall (mm)	0	0	24	21	100	12

Treatments

The experiment aimed to quantify the contribution of sunflower leaves to yield and oil quality through the application of twelve leaf defoliation treatments.

Defoliation treatments (12)

1. Control – no leaves removed (0/3)
2. Budding (2 cm bud) – remove all leaves (3/3)
3. Budding (2 cm bud) – remove top 10 leaves (1/3)
4. Budding (2 cm bud) – remove top 20 leaves (2/3)
5. Budding (2 cm bud) – remove bottom 10 leaves (1/3)
6. Start of flowering (R5.1) – remove top 10 leaves (1/3)
7. Start of flowering (R5.1) – remove top 20 leaves (2/3)
8. Start of flowering (R5.1) – remove all leaves (3/3)
9. Start of flowering (R5.1) – remove bottom 10 leaves (1/3)
10. Flowering complete (R6.1) – remove top 10 leaves (1/3)
11. Flowering complete (R6.1) – remove top 20 leaves (2/3)
12. Flowering complete (R6.1) – remove all leaves (3/3)

Treatments were applied by cutting off the leaves using secateurs, but leaving the leaf axil intact. Treatments were applied on:

Budding cuts – 26 November

Start of flowering (R5.1) – 9 December

Flowering complete (R6.1) – 21 December

Results

Plant height

Five plants in each plot were measured for physiological maturity – taken from ground level up to the point of attachment at the back of the head. The average plant height in the experiment was 131.7 cm. No defoliation treatment affected plant height.

Head diameter and arc length

Five plants in each plot had had head diameter and arc length measured at physiological maturity. Head diameter was measured across the back of the head and arc length across the front face of the head. The average head diameter was 14.1 cm. There were significant treatment differences based on defoliation (Table 3). The smallest head diameters were recorded from removing all leaves at either budding or the start of flowering at 6.9 cm and 8.8 cm, respectively. There was very little difference statistically between many of the treatments.

The average arc length was 21.2 cm and there were significant differences based on the treatments. Removing all leaves at budding and the start of flowering had the largest impact on arc length reducing it to 9.7 cm and 16.2 cm respectively. The remaining defoliation treatments had no significant impact on arc length compared with the non-defoliated control (Table 3).

Table 3. Impact of defoliation treatments on plant structures.

Treatment	Plant height (cm)	Head diameter (cm)	Head arc length (cm)
Control – no leaves removed (0/3)	130.6	16.3	23.5
Budding – remove all leaves (3/3)	121.7	6.9	9.7
Budding – remove top 10 leaves (1/3)	132.1	17.7	24.1
Budding – remove top 20 leaves (2/3)	133.5	13.1	18.8
Budding – remove bottom 10 leaves (1/3)	136.5	15.7	24.3
Start of flowering – remove top 10 leaves (1/3)	135.1	17.1	24.5
Start of flowering – remove top 20 leaves (2/3)	128.7	15.6	19.0
Start of flowering – remove all leaves (3/3)	128.7	8.8	16.2
Start of flowering – remove bottom 10 leaves (1/3)	136.1	17.1	25.7
Flowering complete – remove top 10 leaves (1/3)	134.3	16.1	24.3
Flowering complete – remove top 20 leaves (2/3)	134.0	15.1	22.1
Flowering complete – remove all leaves (3/3)	129.1	13.1	22.5
l.s.d. ($P = 0.05$)	n.s.	3.88	4.11

Grain yield

The average yield was quite low at the site in 2015–16 compared with that normally expected for sunflower crops on the Liverpool Plains, with an experiment average of 1.05 t/ha. There was, however, a large range in the yields as a result of the treatments. Removing the bottom 1/3 of leaves at budding had the highest yield at 2.07 t/ha, however, there was no significant difference in the top four yielding treatments (Figure 1). The lowest yields were obtained from the total leaf removal treatments at 0.16 t/ha.

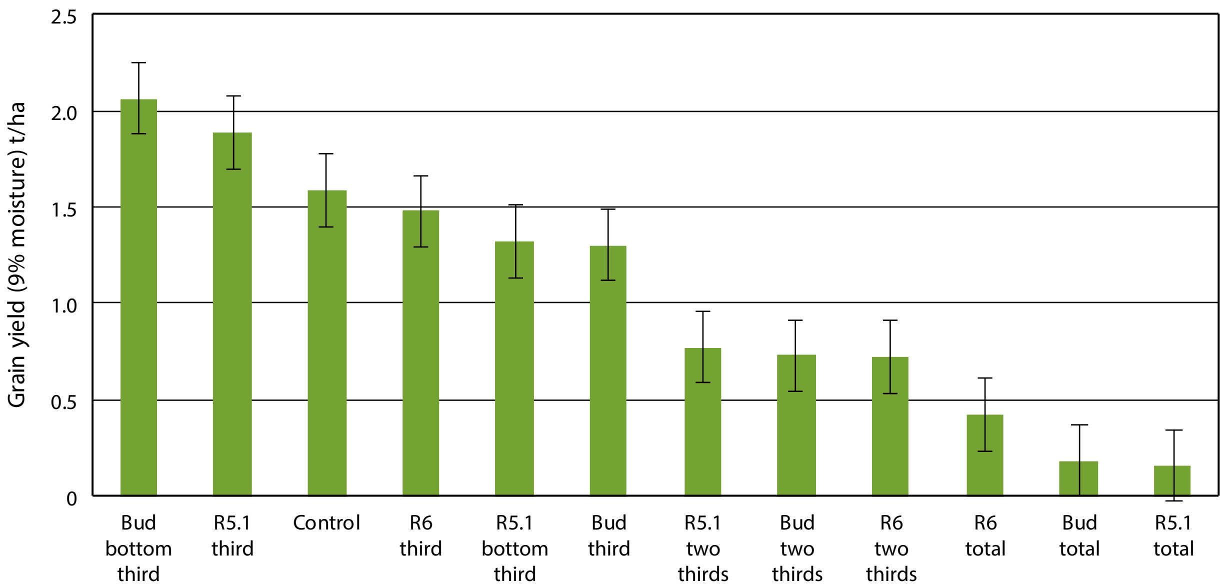

Figure 1. Grain yield of sunflowers 2015–16. R5.1 = start of flowering; R6 = flowering complete.

Grain quality

Sub samples from each plot were collected at harvest and analysed for 1000 grain weight and test weight. Oil contents were not available at the time of publication.

The average 1000 grain weight in the experiment was 47.1 grams. The largest effects on grain weights were obtained in treatments were all leaves were removed, while the smallest impact on grain weight was obtained when only the top 10 leaves were removed (data not shown).

The average hectolitre weight in the experiment was 39.2 kg/hL, which is well above the receival standard of 32 kg/hL. The largest reduction in test weight resulted from removing all leaves at the end of flowering (data not shown).

Conclusions

Grain yields at this site in 2015–16 were, on average, 1.07 t/ha. Removing the bottom 1/3 of leaves had the least impact on grain yield (2.07 t/ha), while removing all leaves had the largest impact (0.16 t/ha).

There were also significant effects on plant structures from the defoliation treatments, namely head diameter and arc length. Removing all leaves at budding or at the start of the flowering growth stages had the largest effect on plant structures. However, removing all leaves at the end of flowering had the largest impact on 1000 grain weight and test weight.

Results from this experiment suggest that the bottom 1/3 of leaves on a sunflower plant is the most expendable.

This experiment is one of a series conducted during the 2015–2017 seasons, comparing the effect of leaf loss on crop yield and quality. These results should be considered carefully until an across-sites and-seasons analysis is completed on the entire data set.

Acknowledgements

This experiment was part of the project *Tactical agronomy for selected crops in the northern region* (*safflower, linseed, sunflower*) (DAN00197), with joint investment by NSW DPI and GRDC. Thanks to Nuseed and Neil Weier for the supply of experiment seed. Technical assistance provided by Delphi Ramsden (NSW DPI), Angus Hombsch, Alice Bowler and Bronwyn Brennan (formerly NSW DPI) is gratefully acknowledged. Thanks also to Neroli Graham, NSW DPI for assisting with data analysis. Thanks to Peter Winton, 'Windy Station', Pine Ridge for hosting the experiment.

Contribution of leaves to the yield of sunflowers – Willow Tree 2016–17

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Key findings

- Sunflower yields were greatly affected by the various defoliation treatments, ranging from 0.12 t/ha to 0.97 t/ha.
- Reductions in yield, of between 55% and 82% compared with the control resulted from total leaf removal at all three of the targeted growth stages (budding, start of flowering and flowering completion) as well as removing two-thirds of the leaves at budding.
- There was no negative effect on grain yield from removing the bottom third of leaves at budding or the start of flowering. Removing the bottom third of leaves at the start of flowering actually provided a slight yield advantage over the control treatment. The largest effect on plant height, head diameter and head arc length were caused by removing all leaves at the budding stage.

Introduction

Sunflowers are generally considered a minor crop in the northern grains region. However, they play an important role in providing a broadleaf summer crop rotation option. An individual sunflower plant produces on average 2000–6,000 cm^2 of leaf area, which drives yield and oil content.

Identifying which leaves contribute most towards yield and oil content helps inform decisions around disease, pest and general crop management in sunflower crops. Whether it is because the crop is infected with a disease such as powdery mildew, or has insect damage e.g. loopers, the end result is a need for growers and advisors to know where and when to spend money in crop protection to achieve the best economic return on investment through maintaining green leaf area.

Site details

Location	'Parraweena', Willow Tree
Co-operator	Joe Fleming
Soil nutrition	The site was soil cored before sowing to determine starting nutrition (Table 1). Starting nitrogen (N) levels were 93.2kg N/ha to a depth of 1.2 m.
Starting soil water and rainfall	The site was soil cored before sowing and found to have 130 mm of plant available water (PAW) to a depth of 1.2 m. Rainfall was recorded at the experiment site (Table 2).
Sowing date	9 October 2016
Fertiliser	150 kg/ha Gold N pre-sowing 10 L/ha Amps Kickstart plus Petrik applied at sowing
Hybrid	Ausigold 62
Harvest date	24 February 2017

Table 1. Soil chemical characteristics.

Characteristic	Depth (cm)				
	0–10	10–30	30–60	60–90	90–120
pH (1:5 $CaCl_2$)	6.4	6.7	7.0	7.8	8.1
Nitrate nitrogen (mg/kg)	14	8	6	6	6
Sulfur (mg/kg)	3.6	5.7	10.8	24.1	47.9
Phosphorus (Colwell) (mg/kg)	37	9	4	10	25
Organic carbon (OC) (%)	1.58	1.0	0.8	0.64	0.46

Table 2. In-crop rainfall at 'Parraweena', Willow Tree in 2016–17.

Month	September	October	November	December	January	February	March
Rainfall (mm)	163.2	93.6	67.6	73.6	66.2	51.8	123.0

Treatments

The experiment aimed to quantify the contribution of different sunflower leaves to yield and oil quality by applying 12 leaf defoliation treatments.

Defoliation treatments (12)

1. Control – no leaves removed (0/3)
2. Budding (2 cm bud) – remove all leaves (3/3)
3. Budding (2 cm bud) – remove top 10 leaves (1/3)
4. Budding (2 cm bud) – remove top 20 leaves (2/3)
5. Budding (2 cm bud) – remove bottom 10 leaves (1/3)
6. Start of flowering (R5.1) – remove top 10 leaves (1/3)
7. Start of flowering (R5.1) – remove top 20 leaves (2/3)
8. Start of flowering (R5.1) – remove all leaves (3/3)
9. Start of flowering (R5.1) – remove bottom 10 leaves (1/3)
10. Flowering complete (R6.1) – remove top 10 leaves (1/3)
11. Flowering complete (R6.1) – remove top 20 leaves (2/3)
12. Flowering complete (R6.1) – remove all leaves (3/3)

Treatments were applied by cutting off the leaves using secateurs, but leaving the leaf axil intact. Treatments were applied on:

Budding cuts – 7 and 8 December 2016

R 5.1 – 23 December 2016

R6.1 – 6 January 2017.

Results

Plant height

The height of five plants in each plot was measured before harvest, taken from ground level up to the point of attachment at the back of the head. The average plant height in the experiment was 141.7 cm. Removing all leaves at the budding stage had the greatest affect on plant height, at only 117.5 cm, a 25% reduction (Table 3).

Head diameter and arc length

The head diameter and arc length of five plants in each plot were measured before harvest. Head diameter was measured across the back of the head and arc length across the front face of the head. The average head diameter was 15.9 cm across all treatments. Total leaf removal at budding had the largest impact on head diameter, reducing it to 3.6 cm. This was closely followed by removing 2/3 of the leaves at budding and removing all the leaves or 2/3 at the start of flowering (Table 3).

The average arc length was 16.5 cm. There were significant differences between defoliation treatments. Removing all leaves at budding had the largest affect on arc length reducing it to 3.2 cm. Removing all leaves at the start of flowering and removing 2/3 of leaves at budding also significantly reduced the arc length to 10.4 cm and 7.3 cm respectively. There was no effect on arc length from all of the 1/3 leaf removal treatments compared with the control (Table 3).

Table 3. Impact of defoliation treatments on sunflower plant structures.

Treatment	Plant height (cm)	Head diameter (cm)	Head arc length (cm)
Control – no leaves removed (0/3)	144.7	19.1	21.4
Budding – remove all leaves (3/3)	117.5	3.6	3.2
Budding – remove top 10 leaves (1/3)	146.8	18.1	17.6
Budding – remove top 20 leaves (2/3)	137.6	9.8	7.7
Budding – remove bottom 10 leaves (1/3)	152.5	19.6	22.2
Start of flowering – remove top 10 leaves (1/3)	146.6	18.1	19.4
Start of flowering – remove top 20 leaves (2/3)	132.9	17.1	16.9
Start of flowering – remove all leaves (3/3)	139.4	11.6	10.4
Start of flowering – remove bottom 10 leaves (1/3)	146.3	19.2	21.2
Flowering complete – remove top 10 leaves (1/3)	139.4	18.1	19.6
Flowering complete – remove top 20 leaves (2/3)	157.3	19.6	20.6
Flowering complete remove all leaves (3/3)	138.9	17.5	17.6
l.s.d. ($P = 0.05$)	13.05	2.36	4.38

Grain yield

Harvested grain yield at 9% moisture ranged from 0.12 t/ha to 0.97 t/ha at this site. There was a large and significant effect from defoliation treatments on yield. The largest effects on yield resulted from removing all leaves at all three of the targeted growth stages (budding, start of flowering and flowering completion). Removing the top 2/3 of the leaves at budding resulted in a similar yield reduction as the total leaf removal treatments (Figure 1).

Removing the bottom 1/3 of leaves at the start of flowering (R5.1) improved yield compared with the control. Removing the top 1/3 of leaves at budding, start of flowering or flowering completion did not affect yield compared with the control, neither did removing the bottom 1/3 of leaves at budding or removing 2/3 of leaves at the start of flowering or flowering completion (Figure 1).

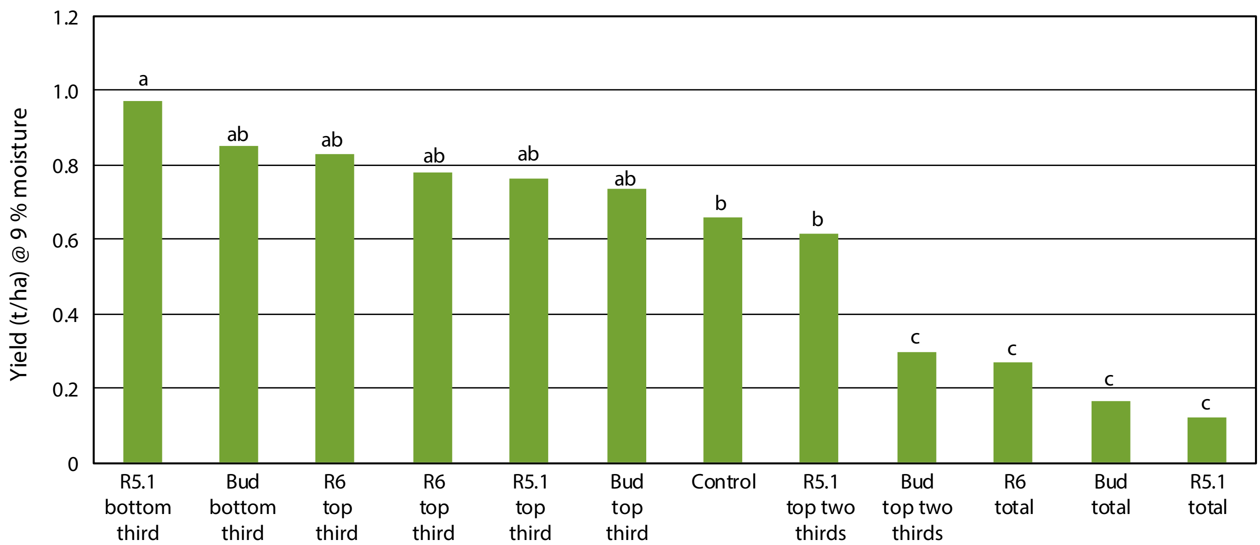

Figure 1. Effect from defoliation treatments on grain yield (t/ha).

Agronomy

Grain quality

Sub samples from each plot were collected at harvest and analysed for 1000 grain weight and test weight. Oil contents were not available at the time of publication.

The average 1000 grain weight in the experiment was 41.2 grams. Defoliation treatments did not significantly affect 1000 grain weight (data not shown).

The average hectolitre weight in the experiment was 35.6 kg/hL, which is well above the receival standard of 32 kg/hL (data not shown).

Conclusions

Defoliation treatments significantly affected grain yields. The largest reductions in yield, between 55% and 82 % when compared with the control, resulted from a treatment where all leaves were removed at all three of the targeted growth stages (budding, start of flowering and flowering completion) and another where the top 2/3 of the leaves were removed at budding.

Removing the bottom 1/3 of leaves at the start of flowering improved yield compared with the control. While removing the top 1/3 of leaves at budding, start of flowering or flowering completion did not affect yield compared with the control, neither did removing the bottom 1/3 of leaves at budding or removing 2/3 of leaves at the start of flowering or flowering completion

The defoliation treatments had significant effects on plant structures, namely plant height, head diameter and arc length. Removing all leaves at the budding stage had the greatest effect on plant height and arc length, causing a 25% reduction in height and an 85% reduction in arc length. Total leaf removal at budding also had the largest effect on head diameter, reducing it to 3.6 cm compared with the control at 19.1 cm diameter.

Therefore, based on the preliminary results generated from this one experiment, it appears that the bottom one third of leaves contribute the least value towards yield on a sunflower plant.

However, this experiment is one of a series conducted during the 2015–2017 seasons, comparing the effect of leaf loss on crop yield and quality. These results should therefore be considered carefully until an across sites and seasons analysis is completed on the entire data set.

Acknowledgements

This experiment was part of the project *Tactical agronomy for selected crops in the northern region* (*safflower, linseed, sunflower*) (DAN00197), with joint investment by NSW DPI and GRDC. Thanks to Nuseed and Neil Weier for the supplying seed for the experiment. Technical assistance provided by Delphi Ramsden, Alice Bowler, Max Cloake and Jim Perfrement (NSW DPI) is gratefully acknowledged. Thanks to Joe Fleming, 'Parraweena', Willow Tree for hosting the experiment. Thanks to Neroli Graham for assistance with the statistical analysis.

Sorghum row direction x configuration x hybrid – Terry Hie Hie 2015–16

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Key findings

- Varying row direction from north–south or east–west did not affect grain yield or quality.
- Row configuration did not affect grain yield, however, there were some effects on grain quality. The solid row configuration produced higher grain protein and screenings levels, but lower test weight than the superwide and single skip treatments.
- There were differences between the hybrids for grain yield and quality. MR Apollo and MR 43 produced higher yields than 84G22. Differences in grain quality were also found, with MR Apollo producing a higher grain protein level and 1000-grain weight than the other two hybrids.

Introduction

Sorghum is an important summer crop in north-eastern NSW, where dryland sorghum yields ranging from 3 t/ha to 5 t/ha are common. In these farming systems, where grower and advisor confidence in growing sorghum is high and a reasonable amount of other research has been conducted on general crop agronomy, the research emphasis is focused more on lifting yields. This is in contrast to research in the drier, western zone where improving confidence and reliability in crop production are the paramount research focus.

The experiment outlined below was designed to compare grain yield and quality responses with variations in row direction (north–south versus east–west) across a range of row configurations (to simulate various light interception orientations) and sorghum hybrids. A second site was planted in the 2015–16 season, located further south at Spring Ridge on the Liverpool Plains.

Site details

Location	'Grattai East', Terry Hie Hie
Co-operator	Michael Ledingham
Soil nutrition	The site was soil cored before sowing to determine starting nutrition (Table 1). Starting nitrogen (N) levels were 49 N/ha to a depth of 1.2 m.
Starting soil water and rainfall	The site was soil cored before sowing and found to have 34 mm of plant available water (PAW) to a depth of 1.2 m. Rainfall was recorded at the experiment site (Table 2).
Sowing date	17 September 2015
Fertiliser	80 kg/ha Starter Z
Harvest date	22 January 2016

Table 1. Soil chemical characteristics.

Characteristic	Depth (cm)				
	0–10	10–30	30–60	60–90	90–120
pH (1:5 $CaCl_2$)	5.9	6.6	7.2	7.1	7.4
Nitrate nitrogen (mg/kg)	7	3	4	2	3
Sulfur (mg/kg)	7.5	3.2	5	4.2	9.5
Phosphorus (Colwell) (mg/kg)	28	9	6	4	3
Organic carbon (OC) (%)	1.28	0.54	0.24	0.13	0.09

Table 2. In-crop rainfall at 'Grattai East', Terry Hie Hie in 2015–16.

Month	September	October	November	December	January
Rainfall (mm)	10	81	0	76	0

Treatments

Row direction

1. North–south
2. East–west

Hybrids

1. MR Apollo
2. MR 43
3. 84G22

Row configuration

1. Solid (1 m spacing)
2. Single skip
3. Superwide (1.5 m spacing)

The experiment was a split-split design with main blocks of row direction and sub blocks of row configuration with hybrids randomised within blocks. Three replicates were used.

Results

Plant structures

Plant establishment was targeted at a population of 50,000 plants/ha. The average plant population recorded was 50,190 plants/ha. Neither row configuration nor hybrid affected the established plant population. There was a significant effect from row direction, with higher plant establishment in the north–south direction at 52,530 plants/ha versus 47,840 plants/ha in the east–west direction.

Tillering was quite low at this site in this season, with only 15,000 tillers/ha produced on average. There was no significant difference between hybrids, row configurations or row direction for tillering.

Similarly, the number of heads produced was not high. There was no significant difference for hybrid or row direction; however there were differences across the row configurations. On average, 61,420 heads/ha were produced across treatments. There were more heads produced in the solid configuration compared with the single skip configuration (67,780 heads/ha vs 56,300 heads/ha). The superwide treatment was not different from either the solid or single skip treatments (60,190 plants/ha).

There were slightly more tillers per plant and heads per plant produced by the east–west row direction than the north–south treatment (data not shown).

Days to flowering

Neither row direction nor row configuration affected the days to 50% flowering. However, there were significant differences between the hybrids. MR 43 was the quickest at 74 days, followed by 84G22 at 75 days. MR Apollo was 4–5 days slower reaching 50% flowering at 79 days.

Grain yield

The site mean grain yield was 3.54 t/ha. Neither row direction nor row configuration affected grain yield at this site in this season. However, there were significant differences in the hybrid performance. MR Apollo and MR 43 performed similarly, producing 3.83 t/ha and 3.58 t/ha respectively, while 84G22 produced less at 3.20 t/ha. There were no significant interactions between the three factors.

Grain quality

The grain protein levels averaged 9.2%. There was a significant interaction between row direction, row configuration and hybrid for protein content, however, no clear pattern was evident, making explaining the results difficult. When examining the significant single factors, the solid row configuration produced higher grain protein than the superwide or single skip treatments. Similarly, MR Apollo produced higher grain protein than the other two hybrids (data not shown). Unfortunately, growers are not remunerated based on protein content, making the differences more important from an academic and nutrient removal point of view.

Test weights showed significant differences based on the treatments for hybrid and row configuration only. The solid row configuration produced a significantly lower test weight than the other two configurations, but well above the receival standards level. MR Apollo also had a lower test weight than the other two hybrids.

Screening levels were low, with a site average of 2.1%. Significant interactions occurred for hybrid and row configuration. The solid plant produced more screenings than the other two configurations. 84G22 produced significantly higher levels of screening than the other two hybrids, but levels were still low.

The only differences in 1000-grain weight were found between hybrids, with MR Apollo having a higher 1000-grain weight than MR 43, which was higher than 84G22.

Conclusions

The effect from row direction on plant structures was minor, with only an increase in plant establishment detected from the north–south direction compared with the east–west direction. This difference did not translate into higher tiller or head production per hectare. There were slightly more tillers per plant and heads per plant from the east–west direction, but again this did not correlate with higher yields.

Row configuration did not affect plant establishment or tillering, however, there were more heads produced per hectare from the solid configuration compared with the single skip. This did not translate into a difference in grain yield; however, there were some impacts on grain quality. The solid row configuration produced higher grain protein and screenings levels, but lower test weights than the superwide and single skip treatments.

There were differences between the hybrids for grain yield, with MR Apollo and MR 43 producing higher yields than 84G22. There were also differences in grain quality, with MR Apollo producing a higher grain protein level and 1000-grain weight than the other two hybrids

The results from this experiment suggest that there is no economic value in altering the sowing direction of rows to either north–south or east–west, or any yield benefit from altering row configuration between solid, single skip or superwide.

Acknowledgements

This experiment was part of the project *Tactical crop agronomy of sorghum and maize in the northern region – NSW component* (DAN00195), with joint investment by NSW DPI and GRDC. Thanks to Pioneer and Pacific Seeds for supplying the seed. Technical assistance provided by Delphi Ramsden, Angus Hombsch, Alice Bowler, Bronwyn Brennan (NSW DPI) is gratefully acknowledged. Thanks to Michael Ledingham for hosting the experiment and Gavin McDouall, HM Ag for his assistance with the site.

Susceptibility of chickpea varieties to seed markings – Tamworth and Trangie 2013–2015

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[1]NSW DPI, Tamworth

[2]NSW DPI, Trangie

Key findings

- The 2013 Tamworth and 2014 Trangie environments were not conducive to high levels of seed markings, with all varieties having <5% tiger stripe/blotches.
- The later sown chickpeas had a lower incidence of seed markings in two of the three environments.
- The 2015 Tamworth experiment was conducive to seed markings for the first sowing date (SD1). In this case, the most susceptible commercial varieties were PBA Pistol[⊕] and PBA Boundary⊕, with 9.7% and 6.7% of individual seeds having tiger stripe/blotches respectively.
- All five kabuli varieties did not display any seed markings in any of the three environments.
- All desi varieties showed at least low levels of tiger stripe/blotch type markings in one or more of the three environments and two sowing dates.

Introduction

Any blemish or mark on chickpea seeds detracts from their visual appeal to consumers and processors. This can negatively affect export prices and market access. At a grower level, seed can be downgraded or rejected depending on the cause of the blemish, such as ascochyta blight; less serious seed markings can be mistaken for ascochyta. For this reason, pre-emptive research is being conducted to minimise the risk of seed markings becoming a future issue in the Australian chickpea industry. There is a range of different seed markings that can occur as blemishes on chickpea seeds. This project is examining the most common one, known as tiger striping or blotching (Figure 1). Research suggests that the blotch-type marking is a more severe tiger stripe, so we now include both in the same classification as they can often occur together on a single seed.

This experiment aimed to compare the incidence of seed markings (tiger stripe/blotch) for a range of commercial chickpea varieties and advanced breeding lines sown on two sowing dates on the central western and north-western slopes of NSW. This information will be used to advise the Pulse Breeding Australia (PBA) chickpea breeding program of genetic susceptibilities. It will also be used to understand environmental triggers, potentially enabling agronomic strategies to be developed to mitigate seed marking incidence in the future.

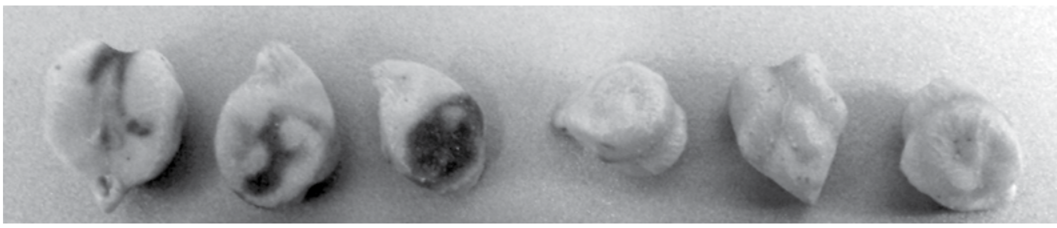

Figure 1. Tiger stripe/blotch type markings of desi chickpea (left) compared with clean seed of the same sample (right).

Site details

Location and years

Tamworth Agricultural Institute, Tamworth NSW – 2013, 2015
Trangie Agricultural Research Centre, Trangie NSW – 2014

Experiment management

Each experiment followed standard agronomic practices. Seeds were treated with label rates of P-Pickel T® (360 g/L thiram, 200 g/L thiabendazole) and metalaxyl (250 g/L) and sown with a minimum of 50 kg/ha of Granulock 12 Zn plus water furrow injected rhizobia. Each experiment was managed for disease, weeds and insects following recommended agronomic practices.

Plant population	Target 30 plants/m²

Treatments

Varieties and advanced breeding lines (20)

Desi (15): PBA Seamer⁽ᵇ⁾, PBA Slasher⁽ᵇ⁾, PBA Boundary⁽ᵇ⁾, PBA Striker⁽ᵇ⁾, PBA HatTrick⁽ᵇ⁾, PBA Pistol⁽ᵇ⁾, Genesis 509⁽ᵇ⁾, Kyabra, Genesis 836⁽ᵇ⁾, Howzat, Gully, Jimbour, line 1, line 2, line 3.

Kabuli (5): PBA Monarch⁽ᵇ⁾, Genesis Kalkee⁽ᵇ⁾, Genesis 090⁽ᵇ⁾, Genesis 079⁽ᵇ⁾, Almaz.

Sowing date (SD)

Sowing date	Location, year		
	Tamworth, 2013	Trangie, 2014	Tamworth, 2015
SD1	22 June	29 May	18 May
SD2	26 July	19 June	15 June

Results

Seed marking incidence

The 2013 Tamworth and 2014 Trangie environments were not conducive to high levels of seed markings with all varieties having < 5% tiger stripe/blotches (figures 2 and 3, respectively).

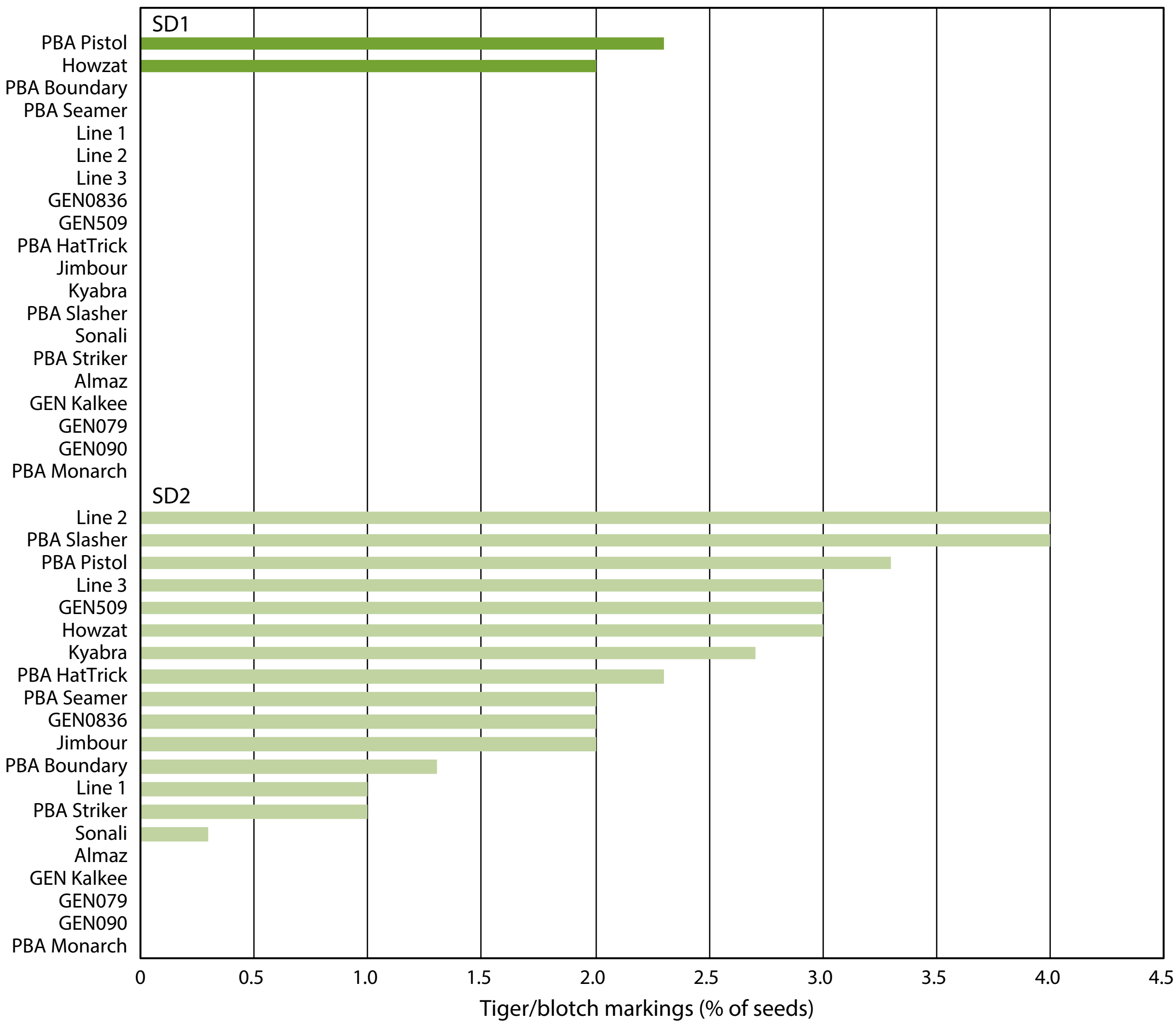

Figure 2. Tiger stripe/blotch type markings (%) of 20 chickpea entries sown at two dates at Tamworth in 2013.

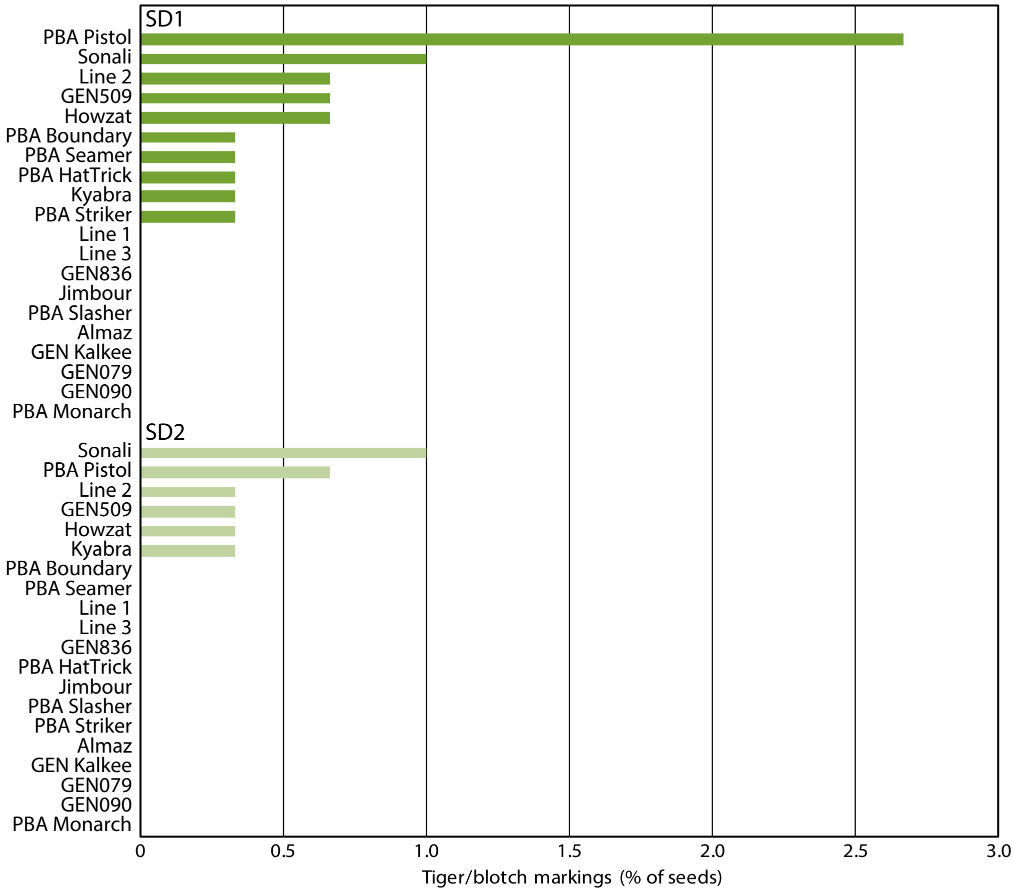

Figure 3. Tiger stripe/blotch type markings (%) of 20 chickpea entries sown at two dates at Trangie in 2014.

The 2013 Tamworth experiment showed a higher incidence of markings for SD2, while the 2014 Trangie experiment showed a higher incidence of markings for SD1. In both cases, the June sowing date had the lower incidence of markings, as the 2013 Tamworth experiment was sown later than normal.

The 2015 Tamworth experiment was conducive to seed markings for the first sowing date (SD1). In this case, the most susceptible commercial varieties were PBA Pistol⁽ᵖ⁾ and PBA Boundary⁽ᵖ⁾, with 9.7% and 6.7% of individual seeds having tiger stripe/blotches respectively, and breeding line 1, with 7.7% markings (Figure 4).

No kabuli chickpeas were affected in any of the experiments or sowing dates, presumably because their seed coats contain no phenolic compounds. Certain phenolic compounds are known to be responsible for flowers, fruit and seeds colour. All the desi varieties showed the ability to produce at least low levels of tiger stripe/blotch-type markings in one or more of the three experiments and two sowing dates.

experiments and sowing dates. Nevertheless, several desi varieties did appear to be generally more susceptible to the tiger stripe/blotch-type marking defect across these environments, particularly PBA Pistol⁽ᵖ⁾, line 2, PBA Boundary⁽ᵖ⁾ and Howzat.

Tiger stripe/blotching appears to have a genetic basis that is triggered by certain environmental conditions in the field. The results of these experiments will be used, in combination with other experiments, to determine the environmental conditions that trigger seeds to mark in this way. This particular set of experiments suggest that sowing in mid June around the Central West and North West Slopes could reduce the percentage of seeds with tiger stripe/blotch-type markings in susceptible desi chickpea varieties.

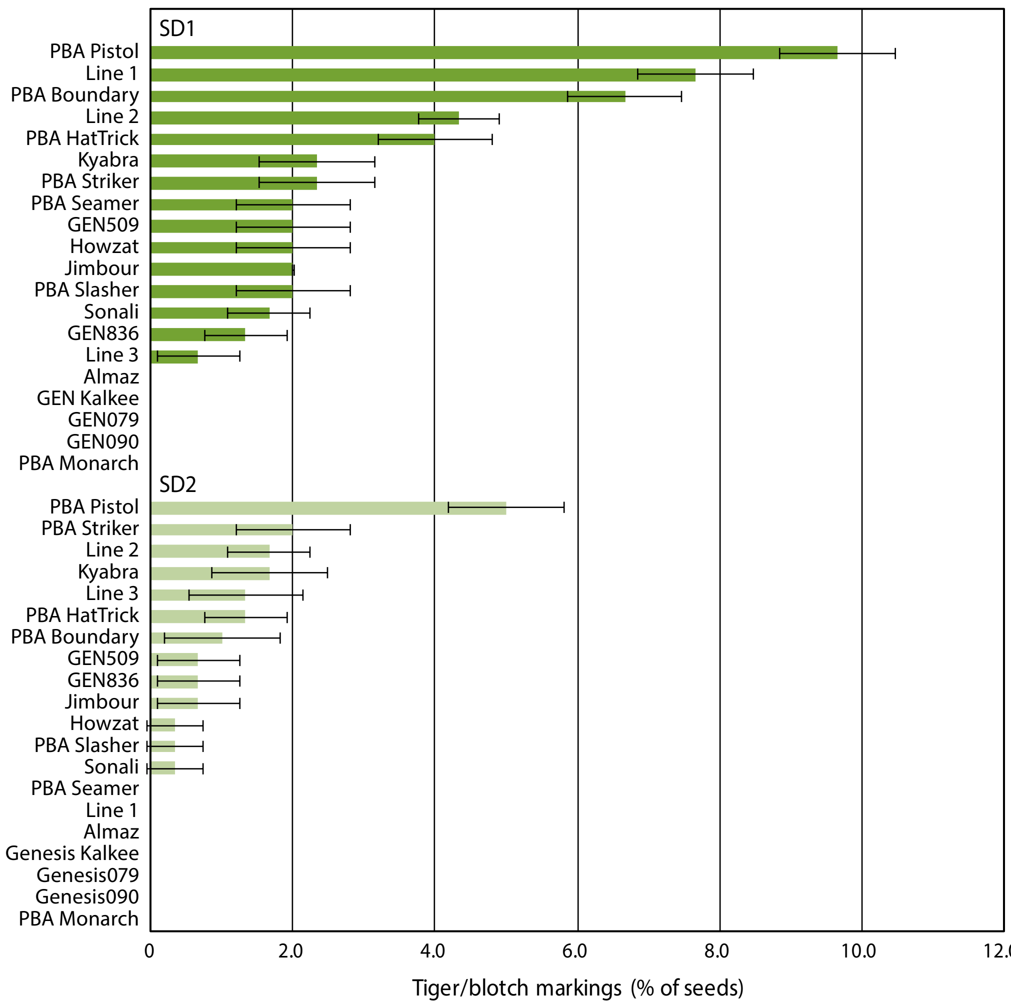

Figure 4. Tiger stripe/blotch type markings (%) of 20 chickpea entries sown at two dates at Tamworth in 2015.

The ranking of desi varieties for tiger stripe/blotch-type markings was not consistent across Conclusions Time of sowing and variety influence the amount of seeds showing tiger stripe/blotching-type markings in chickpeas. Kabuli chickpeas do not suffer from this defect. Desi chickpeas sown in mid June at Tamworth and Trangie had a lower incidence of this type of seed marking.

Research is ongoing to identify both the genetic basis and environmental triggers of tiger stripe/blotch-type markings in desi chickpeas to minimise any potential marketing risk to the Australian chickpea industry.

Acknowledgements

This experiment was part of the project *Eliminating grain defects in chickpeas* (DAN00196; 2014–2016), a collaborative pulse project with joint investment by NSW DPI and GRDC. The evaluation of these experiments were value-adding to project DAS00140 (2013–2015), a collaborative project, with joint investment by SARDI and GRDC and led by Dr Victor Sadras, with these experiments sown by NSW DPI. Technical assistance provided by Narelle Egan, Bec Miller, Matt Grinter, Michael Nowland and Julie Miller (NSW DPI, Tamworth) and Scott Richards, Jayne Jenkins and Liz Jenkins (NSW DPI, Trangie) is gratefully acknowledged.

Susceptibility of chickpea varieties to pod splitting after delayed harvest and impacts on grain yield

Jenny Wood, Catherine Keir, Steven Harden and Andrew Verrell
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Key findings

- Chickpea pods can split open when harvest is delayed (harvest date (HD)3 and HD4), allowing easy access for water and an easier exit for seeds that can drop to the ground before or during the harvest process.
- HD3 averaged 28.6% split pods per plant (varietal range of 2.8–51.9%) while HD4 averaged 46.0% split pods per plant (varietal range of 30.0–64.9%).
- Averaging across HD3 and HD4 for the desi chickpeas, Howzat had the least split pods (10.5%) and PBA Seamer⁽ᵖ⁾ had the most (55.6%). For the kabuli chickpeas, Genesis™ 090 had the least split pods (22.5%) and Genesis™ Kalkee⁽ᵖ⁾ was the worst affected (55.6%).
- Loss of seed from split pods and pod abscission, seed shattering and reductions in grain weight caused from delaying harvest were shown to reduce grain yields by up to 44%.
- A delay of six days with one rain event (44.2 mm) was enough to reduce the grain yield in chickpeas (averaged across varieties) by 2%, due to lower seed density.
- Growers should aim to harvest chickpeas on time to avoid yield losses and grain quality penalties at receival.

Introduction

This experiment aimed to compare the effect of delayed harvest on pod splitting, grain weathering and yield for a range of commercial chickpea varieties.

Delayed harvest results in pod splitting, followed by the pod opening further to drop seeds onto the ground. Pod splitting also allows easier entry of water into the pods, resulting in weather-damaged seeds. This information will be replicated in future experiments and used to advise the Pulse Breeding Australia (PBA) chickpea breeding program about the susceptibility of genetic material to pod splitting.

Site details

Location	Tamworth Agricultural Institute, Tamworth
Sowing date	22 June 2013
Trial management	Each trial followed standard agronomic practices.
Plant population	Target 30 plants/m^2

Treatments

Varieties (10)

Desi (7): PBA Seamer⁽ᵖ⁾, PBA HatTrick⁽ᵖ⁾, PBA Pistol⁽ᵖ⁾, Genesis™ 509, Kyabra⁽ᵖ⁾, Howzat, Gully

Kabuli (3): PBA Monarch⁽ᵖ⁾, Genesis™ Kalkee, Genesis™ 090

Harvest date (HD)

Most varieties started turning on 29 November 2013 and the experiment was desiccated with the contact herbicide Sprayseed (paraquat + diquat) on 15 November 2013.

Table 1. Harvest details.

	Harvest date	Rainfall after desiccation (mm)	Days since prior HD (days)	Rainfall since prior HD (mm) [a]	Thermal time since prior HD (°C days) [b]
HD1	22 Nov	15.8 [c]	0	15.8 (1)[c]	0
HD2	28 Nov	60.0	6	44.2 (1)	126.5 (21.1)
HD3	18 Dec	105.2	20	45.2 (7)	440.9 (22.1)
HD4	13 Jan	128.4	26	23.2 (2)	687.6 (26.4)

a Value in brackets represents the number of rain events since desiccation or the prior HD.
b Value in brackets represents the average daily temperature (°C) during this time period.
c For HD1 the rainfall since desiccation is shown.

Results

Pod splitting

Pod splitting was significantly affected by harvest date (P<0.001) and variety (P<0.001). There was a significant interaction between variety and harvest date (P<0.001) in this experiment (Figure 1).

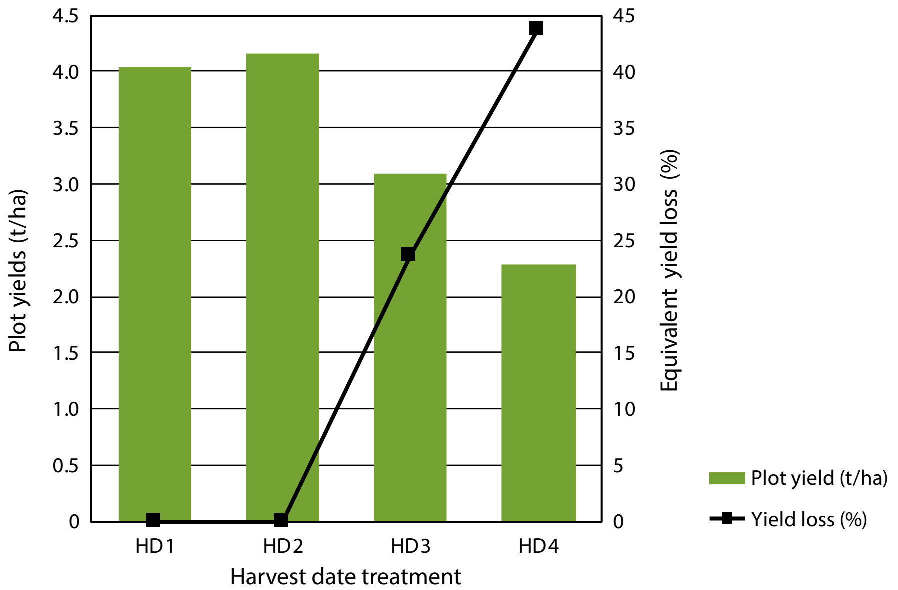

Figure 1. Percentage of pods (per plant) that are split for 10 chickpea varieties at two delayed harvest dates at Tamworth in 2013.

HD1 and HD2 generally had no pod splitting. HD3 had a mean proportion of split pods of 28.6% (varietal range of 2.8–51.9%) while HD4 had a mean proportion of split pods of 46.0% (varietal range of 30.0–64.9%). All varieties showed increased pod splitting from HD3 and HD4, except for PBA Monarch⁽ᵖ⁾. In all other varieties, the difference in the percentage of split pods at HD3 and HD4 ranged from 10.2% to 30.0%, except for Kyabra⁽ᵖ⁾ where the difference was not significantly different.

Averaged across HD3 and HD4 for the desi chickpeas, Howzat had the least split pods (10.5%) and PBA Seamer⁽ᵖ⁾ had the most (55.6%). For the kabuli chickpeas, Genesis™ 090 had the least split pods (22.47%) and Genesis™ Kalkee was the worst affected (55.6%).

Split pods facilitate weather damage to seeds and are one cause of reduced yield at harvest, therefore it is preferable to harvest chickpeas on time to reduce these negative effects on profitability.

Weather damaged grain

Symptoms of weather-damaged grain include changes in colour, low seed density, seed shattering, sprouted seeds and reduced germination and vigour. All of these symptoms, which indicate poor grain quality, can be classified as defects at receival and have marketing implications resulting in lower prices for growers.

Averaged over varieties, the percentage of shattered seeds in the harvested samples were similar for HD1 and HD2 (15–16% by weight), but doubled for HD3 and HD4, being 31.3% and 37.6% respectively (Figure 2).

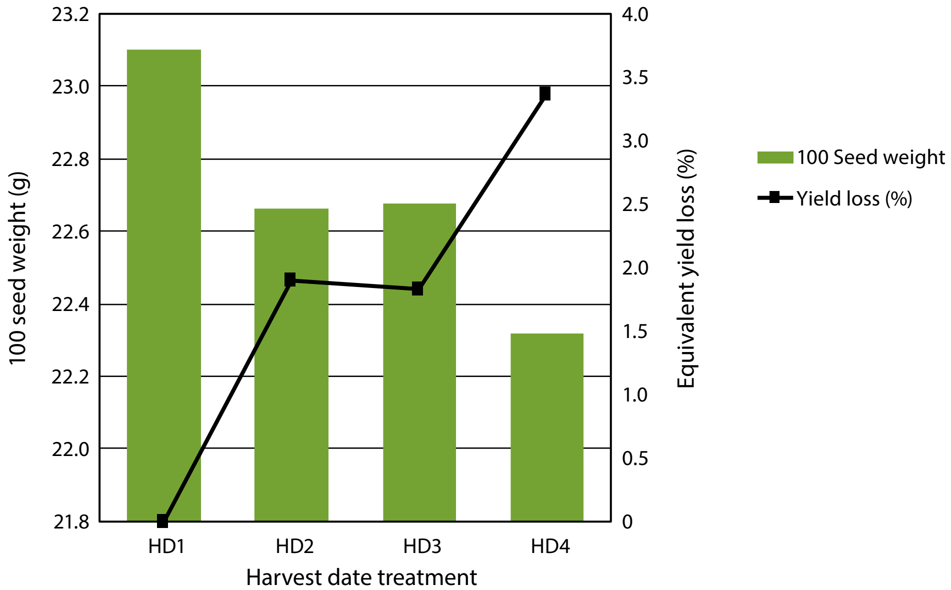

Figure 2. Shattering (averaged across 10 chickpea varieties) at four harvest dates at Tamworth in 2013.

Averaged over varieties, the 100 seed weight (an indicator of seed density) generally decreased with subsequent delayed harvests, from 23.1 g to 22.3 g (Figure 3).

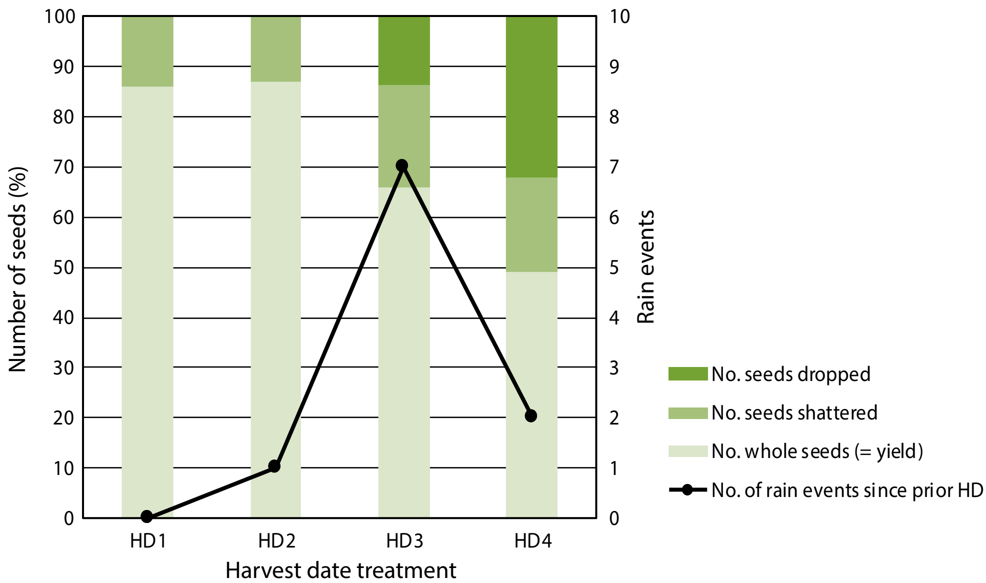

Figure 3. 100 seed weight (averaged across 10 chickpea varieties) at four harvest dates at Tamworth in 2013.

The number of visually sprouted seeds that were harvested was evaluated, but there were not enough to conduct statistical analysis for this trait. The varieties that appear to be most susceptible to sprouting were PBA HatTrick⁽ᵖ⁾, Gully, PBA Seamer⁽ᵖ⁾, and Howzat (albeit at low levels, <3.0% at HD4), while the remaining varieties did not have any visually detected sprouted seeds in this experiment.

Grain yield loss

Yield loss can occur due to delayed harvest due to one or more of the following:

1. pod splitting that can result in grain being dropped onto the ground and left unharvested
2. weather damaged grain that:

a. suffers from weight loss due to enzymatic action resulting in a lower density

b. becomes brittle and shatters, or

c. germinates resulting in sprouted grain

4. pod abscission where the junction between the pod and the peduncle is weakened, resulting in pod loss during harvest (not examined directly in this study).

Averaging over varieties, the plot yields generally decreased with subsequent delayed harvests, from 4.10 t/ha to 2.28 t/ha (Figure 4). This represents a yield loss of 24% for HD3 and 44% for HD4.

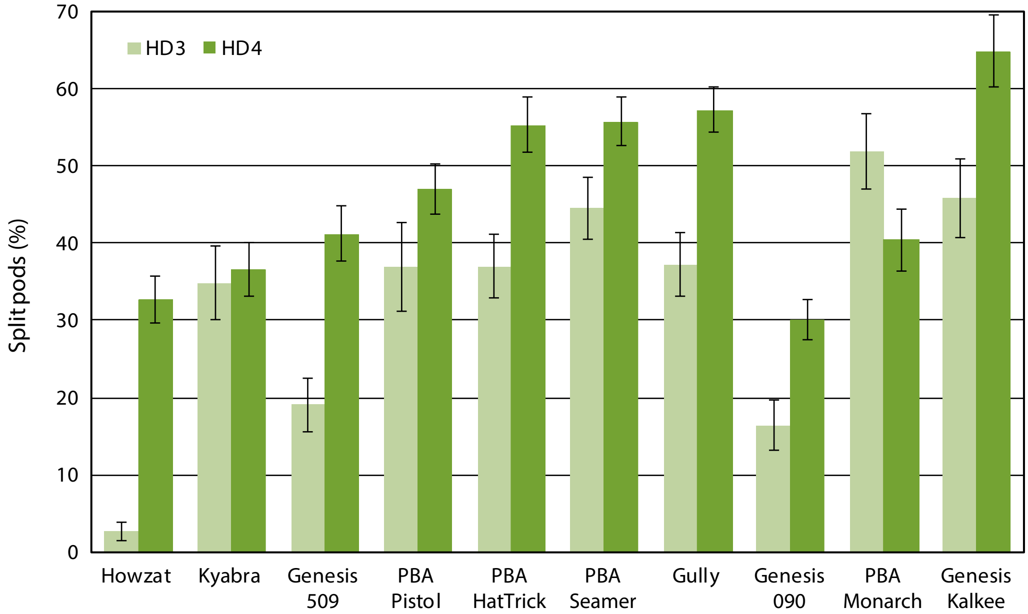

Figure 4. Plot yield (averaged across 10 chickpea varieties) at four harvest dates at Tamworth in 2013.

Yield loss from seed shattering and dropped seeds (either seeds dropping out of split pods or from pod abscission) can be found by combining the results above. Figure 5 shows that delaying harvest causes an increase in both seed shattering and dropped seeds, and the number of dropped seeds doubles from HD3 to HD4.

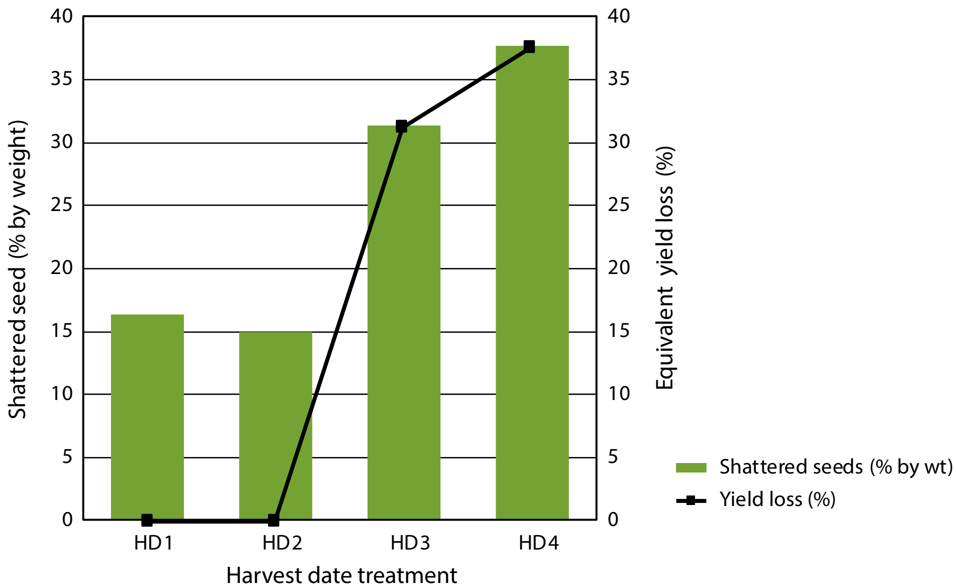

Figure 5. Contribution of seed shattering and dropped seed to reduced plot yields (averaged over 10 chickpea varieties) at four harvest dates at Tamworth in 2013.

Figure 5 shows that yield loss at HD1 and HD2 is primarily through seed shattering (around 14% loss). There was only one rainfall event (albeit significant at 44.2 mm) before HD2, and it had little effect on yield loss. The trial then suffered a series of rain events (seven events, totalling 45.2 mm) before the harvester could get back into the paddock for HD3. This caused a 1.5-fold increase in the amount of seed shattering in HD3 and the emergence of a significant amount of seed lost (14%), as indicated by pod splitting. Total yield loss (based on seed number and ignoring seed weight) for HD3 was 34% (Figure 5). After HD3, the trial suffered from another two small rain events (totalling 23.2 mm), but this was enough to double the amount of seeds dropped from HD4, thereby increasing the yield loss, based on seed number, to 50.8% (Figure 5).

The percentage of split pods (averaged over variety) was 1.6 times higher for HD4 than HD3. If we assume that 90% of the HD3 dropped seeds were from split pods, then we can calculate the increase in split pods for HD4. The difference between total dropped seeds and seeds lost from pod splitting will be seeds lost due to pod abscission (Figure 6).

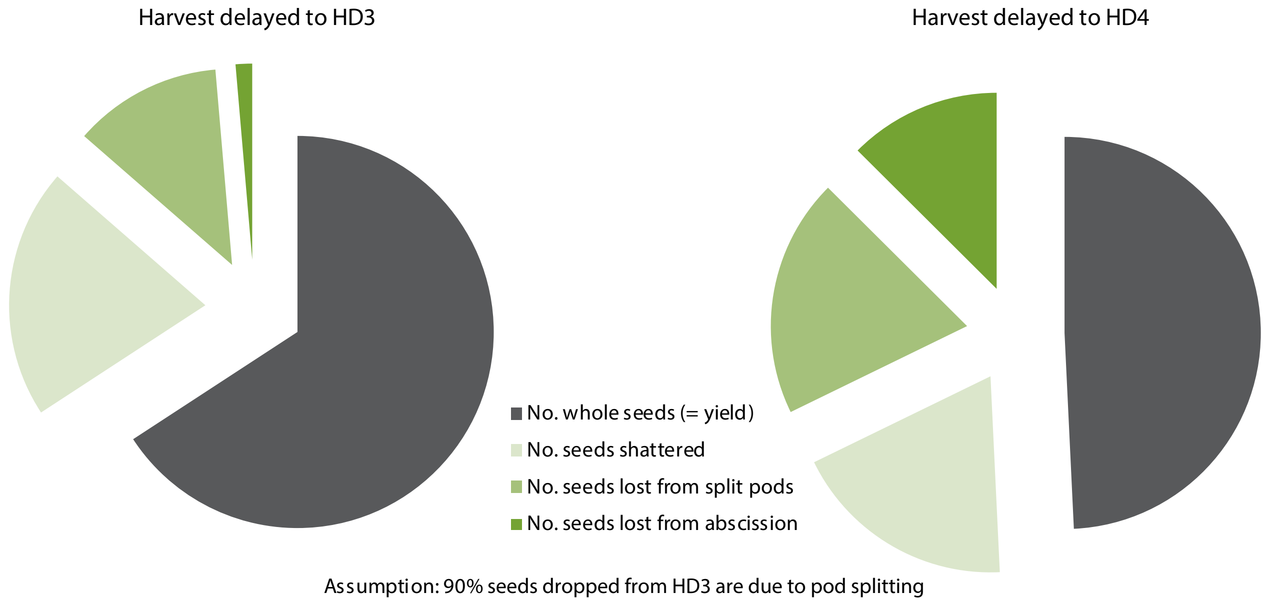

Figure 6. Contribution to reduced plot yields from seed shattering and seed loss due to pod splitting and abscission (averaged over 10 chickpea varieties) when harvest is delayed to HD3 and HD4 at Tamworth in 2013.

Figure 6 shows the estimated contributions of shattered seed and seed loss due to pod splitting and pod abscission to reduced yields for HD3 and HD4, based on seed number. There is a large increase in seed loss from pod abscission at HD4 (from 1% to 13%) and an increase in seed loss due to pod splitting (from 12% to 20%), overall reducing the number of seeds harvested to less than 50%.

The three kabuli varieties were particularly affected by delayed harvests, with a noticeable amount of seeds shed onto the ground compared with the desi varieties.

Growers still need to consider the consequences of delaying harvests:

- HD2 (six-day delay; one rain event = 44.2 mm after HD1) – reduction in grain weight will reduce grain yield. Expect a yield loss of 2%.
- HD3 (a further seven rain events = 45.2 mm) – reduction in grain weight similar to HD2, increase in shattered seeds and seeds falling out of split pods with some pod abscission. Expect a yield loss of 24%.
- HD4 (a further two rain events = 23.2 mm) – reduction in grain weight (approx. 3.4% yield loss) plus increase in shattered seeds and seeds falling out of split pods and pod abscission. Expect a total grain yield loss of 44%.

Desiccation of chickpeas when the grain is physiologically mature can be beneficial by drying out plants and allowing earlier harvesting, potentially before harvesting winter cereal crops. Growers also need to be aware that delayed harvests can cause quality defects that can result in downgrading or grain rejection at receival. So not only does delaying harvest reduce yield, but it can also reduce the price paid per tonne. It is preferable to harvest chickpeas on time to reduce these negative effects on profitability.

Conclusions

Delaying the harvest of chickpeas by 26 and 52 days at Tamworth in 2013 caused significant reductions in grain yield due to loss of seed (from pod splitting and pod abscission) as well as reduced grain quality (lower 100 seed weights and higher percentage of split seeds). HD4 had a 44% grain yield loss compared with HD1. Delaying harvest by only six days (with one 44.4 mm rainfall event) had less negative effects than the repeated wet and dry cycles that affected the two later harvest dates.

Growers need to harvest their chickpea crops on time to achieve the highest yields and seed quality. Desiccation of chickpeas is one strategy that can improve harvestability, by ensuring all pods ripen at the same time and bring the actual harvest process earlier. However, subsequent rain on desiccated crops must be avoided. One significant rain event that delayed harvest by only six days was shown to reduce the 100 seed weight by an amount equivalent to a 2% yield loss (averaged across varieties).

Acknowledgements

This experiment was funded by NSW DPI in the lead up to the project *Eliminating grain defects in chickpeas* (DAN00196; 2014–16), a collaborative pulse project, with joint investment by NSW DPI and GRDC. Technical assistance provided by Michael Nowland (NSW DPI) is gratefully acknowledged.

Crop protection

Disease risk prediction evaluations for phytophthora root rot of chickpeas

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Key findings

- *Phytophthora medicaginis* (Pm) inoculum concentrations decline to low levels (within 6–12 months) of a diseased crop and the distribution becomes more uneven.
- Within 6–12 months, survival populations of Pm (oospores) can be below detectable levels based on both soil DNA and isolate baiting methods.
- These inoculum decline factors limit the ability of PreDicta B to identify paddocks that have a significant disease risk.
- The Pm test is useful for in-crop disease diagnosis when the pathogen is active and inoculum decline has not taken place.

Introduction

Phytophthora medicaginis (Pm), the cause of chickpea phytophthora root rot (PRR), is endemic and widespread in the northern grains region of NSW. Under conducive conditions, PRR can cause 100% loss in chickpea fields. The pathogen survives from season to season on chickpea volunteers, lucerne, native medics, sulla and as resting structures (oospores) in roots and soil. It is known that Pm inoculum concentrations are difficult to detect and quantify in paddocks when a susceptible host such as chickpea is not present.

The South Australian Research and Development Institute (SARDI) has developed a PreDicta™ B soil DNA test to quantify the amount of Pm DNA in soil samples and so provide a measure of the amount of Pm inoculum (infected root tissue and oospores) in paddocks. This study reports on the 2016 season assessment of the capability of this test to:

1. detect Pm in soil from commercial paddocks
2. predict the risk of PRR disease and potential yield losses in chickpea.

Field experiment

Disease and yield loss prediction trial

Location	Hermitage Research Station, Queensland (QLD)
Rainfall and irrigation	There was above average rainfall in June (110 mm) which delayed sowing. July (22 mm) and November (68 mm) rainfall was similar to long-term average values, but for both August (109 mm) and September (91 mm), rainfall totals were well above average – a total of 280 mm of in-crop rainfall.

Trial design	Trial design randomised complete block design with four replicates. Each plot (15 m^2) consisted of four in-furrow inoculated rows; four-row buffer plots were sown around each plot to limit inoculum spread between plots. At sowing and harvest, soil cores (0–150 mm) were collected from the two middle rows of each plot, pooled and analysed for soil Pm concentration by SARDI. PRR disease assessments (% infected plants, or row length of severely infected plants) and grain yields were measured from those same rows.
Sowing date	22 July 2016
Plant population	32 plants/m^2, variety Yorker⁽ᵈ⁾
Harvest date	15 Dec 2016
Treatments	• Oospore treatment: a range of Pm levels were established by applying four concentrations (0, 27, 140 and 494 oospores/plant) of a mixture of oospores (10 isolates) in-furrow at seeding. • Irrigation treatment: irrigated plots were watered (27 mm from 27–29 Nov) with dripper tape delivering between 0.6 to 0.7 mm/hour; the remaining plots had no irrigation

Field survey

Ability to monitor Pm concentrations in commercial paddocks.

Locations	Coonamble in central-western NSW, Moree in northern NSW and Goondiwindi in southern Qld.
Rainfall	Coonamble rainfall June–Oct in 2015 was 112 mm and June–Oct in 2016 was 388 mm. Goondiwindi rainfall June–Oct in 2015 was 20 9 mm and June–Oct in 2016 was 321 mm. Moree rainfall June–Oct in 2015 was 122 mm and June–Oct in 2016 was 323 mm.

Survey methods

Three farms where PRR had been an ongoing problem, and Pm had been isolated from diseased plants, were sampled in April 2016 and again in Nov–Dec 2016. Where possible at each farm, growers or agronomists identified paddocks with ongoing PRR problems, including the area in each paddock where PRR was often first observed or where Pm had been isolated from samples. These areas were designated as hotspots and their GPS position marked.

For hotspot areas, four separate samples were collected following a 'W' collection pattern (32 points along the entire pattern, each point ~6 m apart, using a 150 mm depth corer) in each paddock. At each collection point, the four cores for each separate sample were taken from a single stubble row, with each core taken 2–3 cm apart.

Low lying areas of paddocks where there was pooling following rainfall (below contour banks, low areas of paddocks, dips) were sampled and raised or uniform areas were also collected. These areas provided three bulked samples (32 cores each) for "low areas" and three bulked samples (32 cores each) high areas" from each field; their GPS positions were also marked. Using this method, 12 paddocks were sampled in April 2016, another four paddocks were also sampled with either only hotspot or only low vs high samples collected.

For the April samples, three soil samples from each hotspot and all low vs high samples were sent to SARDI for analysis. The fourth hotspot sample was assessed for Pm in a glasshouse baiting experiment (five reps, cv. Sonali grown in a soil–sand mix). At the end of the baiting experiment, the soil–sand media in each cup was sent to SARDI for analysis.

In the November–December sampling period, all hotspot sites were resampled, all low vs high sample sites were revisited and samples collected from chickpea paddocks in 2016 showing any disease problems.

Results

Field experiment: disease and yield loss predictions

Trial results provided a poor relationship between Pm DNA values and both disease ($R = 0.17$) and yield ($R = -0.22$). However, high R values for PRR measurements and yield ($R = -0.70$) in the trial supported the assumption that the yield loss was predominately due to PRR.

The 2016 trial results consisted of a large number of nil DNA plots post-sowing, that later showed PRR symptoms (Table 1). Pm control samples included for analyses with these samples gave expected DNA values. It is not known why so many 2016 samples gave negative Pm DNA results yet PRR symptoms occurred in the plots.

Crop protection

Table 1. Number of plots (of 40) that had nil Pm DNA results after inoculation and the number of these plots that had PRR symptoms or not.

Post-sowing Pm DNA values		
Total nil DNA values	**nil DNA values & nil PRR symptoms**	**nil DNA values & PRR symptoms**
33/40	2/40	31/40

It could be expected that the probability of a false negative for paddock samples might be higher than those for small-plot replicated field trials as:

1. a single sample–single result from a paddock will be used to assess PRR disease risk
2. the sampling intensity per unit area of paddocks will be much lower than those of plots in field trials.

Field survey: April 2016 paddock inoculum results, detection variability

Six of the 13 paddocks with hotspot soil samples had positive Pm DNA results; all but one of these paddocks grew chickpeas in 2015 (Table 2). Of the six paddocks with positive DNA results, only two paddocks had all three samples test positive.

Given the close proximity (2–3 cm apart) of the cores sampled at each of the 32 points in a hotspot area, the variability in positive DNA results among the three samples warrants consideration. The results for paddocks 10 and 11, and in particular, for paddocks 3 and 13, indicate an uneven distribution of inoculum giving differing results, even for closely-collected soil samples.

Table 2. April 2016 hotspot sample location, paddock code, prior crop (wh:wheat, cp:chickpea), average hotspot sample Pm DNA and number of positive hotspot samples, April 2016 hotspot sample isolate baiting results (no. cankers, no. of putative Pm cultures) and post-experiment DNA results of baiting media.

Location	Code	2015 crop	Av. hotspot P. med DNA sequences/ g soil	Hotspot no. + samples	Av. no. cankers/cup	Total no. putative cultures	Av. P. med DNA sequences/g media
Coonamble	1	wh	0	0/3	0	0	0
Coonamble	2	wh	0	0/3	0	0	0
Coonamble	3	cp	209	1/3	0	0	205
Coonamble	4	cp	0	0/3	0	0	0
Coonamble	5	cp	0	0/3	0	0	0
Coonamble	6	cp	0	0/3	0	0	0
Coonamble	7	cp	0	0/3	0	0	544
Coonamble	8	cp	0	0/3	0	0	0
Goondiwindi	9	cp	1389	3/3	3	6	334767
Goondiwindi	10	cp	1205	2/3	2.8	9	348014
Goondiwindi	11	cp	690	2/3	0.75	2	618706
Goondiwindi	12	cp	2881	3/3	3	7	186981
Moree	13	wh	339	1/3	0	0	0

The baiting experiment results supported the soil DNA results, including that Pm inoculum was unevenly distributed in these samples.

PRR is often first seen to occur in low-lying areas of paddocks where water pooling occurs after heavy rainfall. However, results for hotspot detection success showed that using local knowledge to target sampling to areas where PRR had been observed, gave a slightly better success (4/11 cases) than just targeting low areas of paddocks (3/11 cases) (data not presented).

April vs November 2016 inoculum results, unexpected increases

Results for four Coonamble paddocks with nil Pm DNA results in April 2016 (Table 3) show increases from nil inoculum in a:

- break crop to substantial inoculum in chickpeas including areas with PRR-like symptoms (paddocks 1 and 2)
- prior chickpea crop to substantial inoculum in chickpeas including areas with PRR-like symptoms (paddocks 3 and 5).

Similar results were observed for two Goondiwindi paddocks that were in wheat in winter 2015 and contained no hotspots. The April low and high areas all returned 0 Pm DNA results. However, in November after a chickpea crop, the low sites were positive in one paddock, and low and high sites were also positive in a second paddock (results not presented). This second paddock, which was planted to a PRR-susceptible kabuli variety, had large areas of PRR losses. That high sites returned positive values suggests that the inoculum was resident at these sites, rather than due to inoculum arriving after April via the flow of storm water containing inoculum.

These results were unexpected (although from a small number of paddocks in a single season with high rainfall), as they indicate that testing before sowing a crop might not indicate future disease risk and associated inoculum concentrations.

Table 3. November 2016 average Pm DNA values for four Coonamble paddocks.

Paddock code	2015-2016 crop	November 2016		
		Hot av.	Low Av.	High Av.
1	wh-cp	0*	13,110[c]	4,107[d]
2	wh-cp	1,242[a]	6,447[d]	2,936[d]
4	cp-cp	0	6,662[c]	13,248[d]
6	cp-cp	3,417[b]	–[#]	–[#]

Number of positive Pm DNA samples (in superscript) for soil samples from a single hotspot area, low areas and high areas of paddocks. * only dead seedlings present in hotspot area, possible death from waterlogging; [a] 1 of 3 samples positive; [b] 2 of 3 samples positive; [c] 3 of 3 samples positive; [d] less than 3 samples collected as not all sites had disease symptoms; [#] no disease symptoms observed, no soil samples collected.

Conclusions

This work has not been able to develop disease risk categories for PRR in chickpeas using pre-sowing soil inoculum concentrations. Disease predictions can be affected by:

- the ability in wet seasons for low concentrations of Pm to multiply rapidly to cause PRR
- as Pm inoculum can also spread to neighbouring crops in run-off water.

Detection issues post-harvest and in break crops are the result of:

- Pm declining to low levels during break crops within 6–12 months
- low resting spore concentrations
- uneven distribution of inoculum across paddocks.

However, the Pm DNA test is a useful in-crop tool for growers and agronomists to confirm PRR diagnosis. For example, in 2016 some chickpea paddocks in north-western NSW were saturated causing some areas of the paddocks to die. Pm DNA analysis of soil samples from some of these areas has allowed agronomists and growers to identify if waterlogging or PRR caused the death.

Where PRR is suspected in chickpea crops, confirmation through isolating the pathogen from diseased tissue can be unsuccessful if the symptoms are advanced or the plants have died. Analysing soil samples for Pm DNA provided confirmation of a suspected case of PRR in QLD in 2015.

The key point to using this diagnostic tool will be the need to collect in-crop soil samples when the pathogen is active and inoculum concentrations are high.

Acknowledgements

This research was part of the projects *National improved molecular diagnostics for disease management* (DAS00137) and *Managing crop disease – improving chickpea pathogen resistance (PRR)* (DAN00172), with joint investment by NSW DPI and GRDC. We thank growers for their significant contributions through both trial cooperation, paddock access and the support of the GRDC. Assistance provided by Gail Chiplin, Paul Nash, Amy Alston, Amy Trebilco, Belinda Rowe (NSW DPI), and Taylor Mentha (DAFQ) is greatly appreciated.

Faba bean fungicide efficacy trials – Breeza 2016

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Key findings

- In a year of high disease pressure, most fungicides did not provide a yield and seed size benefit when used at low frequency.
- A high frequency fungicide strategy provided yield benefit using a number of products.

Introduction

In wet years, foliar disease can cause large economic loss in faba bean and there is limited knowledge of the comparative efficacy of different products and different application strategies. This study aimed to compare fungicides for their effectiveness to control diseases as well as improve yield and seed size in faba bean. Experiment one used a low frequency (LF) program, while experiment two involved a high frequency (HF) fungicide program.

Site details

Location	Liverpool Plains Field Research Station, Breeza
Co-operator	Scott Goodworth
Soil type	Black vertosol
Rainfall	A total of 495 mm rainfall was recorded at the experimental site between sowing and harvest, which encouraged development of foliar disease.
Experimental design	Split plot design with fungicide as the main plot and varieties as sub-plots; three replications.
Sowing date	27 April
Fertiliser	Nil
Plant population	Target 20 plants/m²
Weed management	Post-sowing/pre-emergent Terbyne® 1 kg/ha (terbuthylazine 750 g/kg) applied on 27 April.
Insect management	Insect pressure was low and no insecticides were used.
Harvest date	21 November

Treatments

Varieties (3)	PBA Warda⁽ᴰ⁾, PBA Nasma⁽ᴰ⁾ and Fiord
Fungicides (5)	See Table 1 for fungicide treatments.
Fungicides programs	Fungicides were applied before rain on: • LF: application of fungicides (Table 1) on 16 June and 18 August • HF: application of fungicides (Table 1) on 16 June, 1 August, 18 August, 9 September

Table 1. Fungicides and rates used in both fungicide experiments at Breeza 2016.

Active ingredient[1]	Active ingredient (g/L or kg product)	Rate product used (L or kg/ha)
Procymidone	500 g/L	0.50
Carbendazim	500 g/L	0.50
Chlorothalonil	720 g/L	1.50
Mancozeb	750 g/kg	1.00
Tebuconazole	430 g/L[2]	0.35

[1] NSW DPI research is covered under a permit to use off-label crop protection products and application rates on experimental plots (PER7250).
[2] Applied rate was higher than the 145 mL/ha permit rate for tebuconazole on faba bean.

Crop protection

Results

Early disease development

The experiments were located next to a faba bean rust (*Uromyces viciae-fabae*) screening experiment where a high disease level was initiated by sowing rust-susceptible spreader plots, distributing pots with greenhouse-grown rust-infected plants and repeated inoculations with rust spore suspension. The resulting high disease pressure provided a continuous load of rust inoculum to the fungicide experiments. Rust was noted in the disease management experiments soon after plant emergence and developed rapidly in non-fungicide-treated plots. Towards the end of July a high incidence of Stemphylium blight (*Stemphylium* spp) symptoms was noted. On 10 August, plots were scored (% leaf coverage) for both rust and Stemphylium blight.

Impact of early fungicide application on disease symptoms

On 10 August both the LF and HF experiments showed a significant ($P<0.05$) reduction of rust infection levels for the tebuconazole and mancozeb treatments (Tables 2 and 3) compared with the carbendazim, procimidone and unsprayed control. No difference for Stemphylium blight was noted in the LF experiment on 10 August, but the extra tebuconazole application in the HF experiment on 1 August resulted in a significant ($P<0.05$) difference from the control, with procymidone and carbendazim treatments both showing a non-significant trend to greater incidences of Stemphylium blight (Table 3). No interactions were found between fungicide treatment and variety for rust or Stemphylium blight scores.

Varietal differences in disease

Averaged over treatments, Fiord had significantly ($P<0.05$) more rusted leaf area in August than PBA Nasma⫯ or PBA Warda⫯ (data not shown). For Stemphylium blight, the genotype effect in both experiments was highly significant ($P<0.001$) with PBA Warda⫯ showing a very high level of susceptibility and PBA Nasma⫯ significantly less affected than Fiord (data not shown).

Late disease development

Chocolate spot (*Botrytis fabae*) became noticeable in late August and progressed very fast after a number of high intensity, long duration rainfall events. Rust and chocolate spot severities were recorded on 27 September. On 30 September, plots were scored for leaf retention using a 1–5 scale (1 = no leaves dropped; 3 = 50% of the leaves dropped; 5 = > 90 % of the leaves dropped). Stemphylium blight appeared not to progress further after August. On 27 September only minor Stemphylium blight symptoms were noted on the top leaves, but both rust and chocolate spot reached high incidences.

Impact of late fungicide application on disease symptoms

Fungicide treatments were less successful in reducing rust and chocolate spot symptoms later in the season. There was little difference amongst treatments for rust on leaves, while rust severity of the procymidone treatments was significantly ($P<0.05$) higher than the control in both LF and HF application (Tables 2 and 3), and carbendazim was higher ($P<0.05$) in the HF application. There was no difference in chocolate spot severity between treatments in the LF experiment. In the HF experiment chlorothalonil gave a significantly better (P<0.05) result than carbendazim and tebuconazole, but was no different from mancozeb and procymidone.

The poor performance of carbendazim and procymidone for chocolate spot control was surprising, given that both are considered to be the fungicides of choice for chocolate spot control.

The tebuconazole-treated plots showed a significantly higher level of leaf retention than all other treatments in the HF experiment (Table 3).

Table 2. Fungicide efficacy experiment – LF, summary of treatment averages for disease scores (% coverage) and leaf retention (1–5), Liverpool Plains Field Station, 2016.

Treatment	Rust (leaf) August	Stemphylium (leaf) August	Rust (leaf) September	Rust (stem) September	Chocolate spot September	Leaf retention September
Control	8.2^{b}	7.1	13.8^{ab}	17.8^{ab}	23.9	4.1
Procymidone	9.7^{b}	5.9	25.3^{c}	28.9^{c}	25.8	3.8
Carbendazim	7.3^{b}	5.1	18.7^{abc}	21.3^{abc}	21.9	3.8
Chlorothalonil	5.9^{ab}	5.4	13.9^{ab}	16.9^{ab}	21.1	3.8
Mancozeb	2.3^{a}	5.1	8.0^{a}	8.1^{a}	25.0	3.9
Tebuconazole	2.1^{a}	4.4	11.0^{ab}	14.5^{ab}	22.9	3.5
Average	5.9	5.5	15.1	17.9	23.4	3.8
l.s.d. (5%)	4.6	ns	8.8	8.1	ns	ns

*Numbers followed by the same letters are not significantly different (P = 0.05)

*ns = not significant

Table 3. Fungicide efficacy experiment – HF, summary of treatment averages for disease scores (% coverage) and leaf retention (1–5), Liverpool Plains Field Station, 2016.

Treatment	Rust August	Stemphylium August	Rust (leaf) September	Rust (stem) September	Chocolate spot September	Leaf retention September
Control	11.0^{bc}	5.9^{bc}	14.6^{a}	14.5^{b}	21.7^{c}	4.3^{d}
Procymidone	12.1^{c}	7.3^{c}	32.8^{b}	35.0^{c}	17.9^{abc}	3.7^{c}
Carbendazim	10.2^{bc}	7.0^{bc}	25.9^{b}	20.8^{b}	19.0^{bc}	3.3^{b}
Chlorothalonil	6.4^{ab}	5.3^{ab}	13.8^{a}	17.6^{b}	12.4^{a}	3.2^{b}
Mancozeb	4.4^{a}	4.9^{ab}	7.8^{a}	5.6^{a}	13.8^{ab}	3.4^{bc}
Tebuconazole	2.0^{a}	3.8^{a}	5.8^{a}	14.8^{b}	20.1^{c}	2.6^{a}
Average	7.7	5.7	16.8	18.0	17.5	3.4
l.s.d. (5%)	4.9	2.1	10.0	8.2	5.9	0.3

* Numbers followed by the same letters are not significantly different(P = 0.05)

Grain yield

Under severe rust pressure, tebuconazole was clearly the best treatment with a 20% and 68% increase in grain yield compared with the unsprayed control in the LF and HF experiments respectively (Tables 4 and 5). Fungicide treatments had a significant (P<0.05) effect on seed weight in the HF experiment where tebuconazole clearly provided a more positive effect than other treatments.

Comparing the effect of the different fungicides on the three diseases present, it is likely that most of the yield gains in these experiments resulted from controlling rust, but not chocolate spot or Stemphylium blight. It should be noted that the rust inoculum pressure in the experiments was far higher than would normally be present under commercial conditions.

Table 4. Fungicide efficacy experiment – LF, summary of treatment averages for yield components, Liverpool Plains Field Station, 2016.

Treatment	Yield (t/ha)	100 seed weight (g)
Control	2.4[ab]	56.6[b]
Procymidone	2.3[a]	53.2[a]
Carbendazim	2.6[ab]	52.0[a]
Chlorothalonil	2.6[ab]	54.0[ab]
Mancozeb	2.6[bc]	56.7[b]
Tebuconazole	2.9[c]	54.7[ab]
Average	2.6	54.5
l.s.d. (5%)	0.3	2.8

*Numbers followed by the same letters are not significantly different ($P = 0.05$)

Table 5. Fungicide efficacy experiment – HF, summary of treatment averages for yield components, Liverpool Plains Field Station, 2016.

Treatment	Yield (t/ha)	100 seed weight (g)
Control	2.2[a]	54.4[bc]
Procymidone	2.5[a]	50.9[a]
Carbendazim	3.0[b]	52.2[ab]
Chlorothalonil	3.1[b]	53.5[ab]
Mancozeb	3.2[b]	56.1[c]
Tebuconazole	3.7[c]	59.1[d]
Average	3.0	54.4
l.s.d. (5%)	0.4	2.6

*Numbers followed by the same letters are not significantly different ($P = 0.05$)

Conclusions

The high rust pressure and frequent rainfall towards the end of the season was likely responsible for the poor fungicide response in the LF experiment in terms of reducing symptoms and improving yield and seed size. In the HF experiment, mancozeb and tebuconozole were most effective overall in reducing symptoms and improving yield and seed size.

Four of the five fungicides were effective in increasing yield in the HF experiment compared with only one in the LF experiment, indicating the need for repeated sprays when disease pressure is high.

Note that the permit for tebuconazole allows for only three applications of 145 mL/ha in commercial crops.

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Impact of winter cereal crop choice and sowing date on final soil populations of *Pratylenchus thornei* – Tulloona 2015

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Key findings

- Winter cereal crop and variety choice can have a large impact on *Pratylenchus thornei* (*Pt*) population build-up within paddocks.
- Averaged across winter cereal entries, final *Pt* densities were 83% higher when sown in early May compared with early June.
- Final *Pt* populations were between 1.6 and 4.7 times higher in 14 of the 24 barley entries, the durum line 190873, and 12 of the 19 bread wheat entries when sown in early May compared with early June.
- The additional population build-up with early May sowing generally increased the risk level for yield loss in the following wheat crop from either low to medium, or medium to high compared to sowing in early June.
- Although earlier sowing can reduce yield loss associated with both crown rot (CR) and *Pt*, it does, however, appear to favour higher *Pt* population development in some winter cereal varieties, which could exacerbate negative consequences on following crops and/or varieties in the rotation.

Introduction

The root lesion nematode (RLN) *Pratylenchus thornei* (*Pt*) is widespread in cropping soils throughout northern NSW and southern Qld. Winter cereal varieties differ in their extent of yield loss from *Pt* (tolerance) and the numbers of nematodes that multiply in their root systems within a season (resistance). Resistance to *Pt* is an important consideration as it dictates a variety's effect on subsequent crops in the rotation. That is, more susceptible varieties allow greater *Pt* multiplication in their root systems over a season. The higher the resulting *Pt* population left in the soil, the greater the potential for a negative effect on the yield of subsequent crops.

Previous NSW DPI research has demonstrated that earlier sowing can reduce losses to crown rot, caused predominantly by *Fusarium pseudograminearum* (*Fp*), by bringing the grain-filling period forward to when temperatures are generally lower and less favourable to disease expression (Simpfendorfer et al. 2016). Sowing date is also an important consideration to maximise yield potential within a given season; delayed sowing dates are usually associated with significant yield penalties (Graham et al. 2016). However, in the northern grains region, sowing date and variety maturity need to be balanced against the risk of excessive early vegetative growth depleting soil moisture reserves before grain filling, and the risk of frost versus terminal heat stress during flowering and grain development.

Recent modelling research highlights that sowing date can also influence the multiplication of *Pt* through interactions with temperature differences created in the soil profile. Simulations showed that a late May sowing date in southern Qld limited *Pt* densities in the soil profile by allowing roots to develop in soil cooler than a late April, late June or late July sowing date (Thompson 2015).

The effect of two sowing dates on final *Pt* populations was examined in a range of durum, bread wheat and barley varieties near Tulloona in north-western NSW in 2015.

Site details

Location	'Myling', Tulloona
Co-operator	Jack and Julia Gooderham
Sowing dates	6 May and 4 June 2015
Fertiliser	90 kg/ha Urea and 70 kg/ha Granulock Z at sowing
Starting nitrogen (N)	137 kg N/ha to 120 cm

PAWC	~209 mm plant available soil water (0–120 cm)
Rainfall	The growing season rainfall was 150 mm
PreDicta B	2.5 *Pratylenchus thornei*/g soil (medium risk), nil *P. neglectus* and 2.0 log *Fusarium* DNA/g (medium crown rot risk) at sowing (0–30 cm)
Post-harvest soil sampling date	19–20 January 2016 with a bulk of 10 cores (0–30 cm) per plot

Treatments

Varieties (48)

- Twenty-four barley entries (Table 1)
- Five durum wheat entries (Table 1)
- Nineteen bread wheat entries (Table 1)

Pathogen treatment

Added or no added crown rot at sowing using sterilised durum grain colonised by at least five different isolates of *Fp* at a rate of 2.0 g/m of row at sowing.

Results

Averaged across entries (genotype) and sowing date, final *Pt* densities were 10% higher (4.3 *Pt*/g soil) in the no added CR treatment compared with the added CR treatment (3.9 *Pt*/g soil). However, there was no interaction between CR treatment and genotype or sowing date. Averaged across entries and CR treatment, final *Pt* densities were 83% higher (5.5 *Pt*/g soil) when sown on 6 May compared with 4 June (3.0 *Pt*/g soil). The interaction of sowing date with CR treatment was not significant but there was a significant interaction between genotype and time of sowing ($P = 0.061$).

There was a 10.8 fold difference in *Pt* densities between the lowest (Compass⁽ᵖ⁾, WI4896 and DBA Aurora⁽ᵖ⁾) and highest (Elmore CL Plus⁽ᵖ⁾) entry when sown on 6 May and a 9.6 fold difference in *Pt* densities between the lowest (WI4896 and DBA Aurora⁽ᵖ⁾) and highest (Elmore CL Plus⁽ᵖ⁾) entry when sown on 4 June (Table 1). There were significant differences between entries in each of the three winter cereal crop types at each sowing date with the most susceptible barley, durum and bread wheat entries being Gairdner⁽ᵖ⁾, Jandaroi⁽ᵖ⁾ and Elmore CL Plus⁽ᵖ⁾, respectively. Generally, there was lower variation in final *Pt* populations with the durum entries, which were on the lower end, than with barley and bread wheat varieties, which had a larger spread between entries.

Final *Pt* densities were significantly higher with the earlier sowing date (6 May) compared with delayed sowing (4 June) in 14 of the 24 barley entries, the durum line 190873, and 12 of the 19 bread wheat entries (Table 1). Final *Pt* populations were between 1.6 (LPB09-0358) and 4.7 times (LRPB Lancer⁽ᵖ⁾) higher when sown on 6 May compared with the delayed 4 June sowing date.

Crop protection

Table 1. Final *Pratylenchus thornei* soil populations (*Pt*/g soil; 0–30 cm) produced by 24 barley, 5 durum and 1 bread wheat entry on two sowing dates – Tulloona 2015.

Crop	Entry	6 May		4 June	
Barley	Compass⟨D⟩	1.9	a-j	1.4	a-d
	WI4896	1.9	a-j	1.1	a
	Urambie⟨D⟩	2.5	c-p	1.2	ab
	SY Rattler⟨D⟩	2.8	e-s	1.9	a-i
	WI4897	3.0	f-u	1.2	ab
	Oxford⟨D⟩	3.4	i-x	2.5	c-o
	NRB121156	3.6	k-z	1.3	a-c
	Commander⟨D⟩	3.9	l-A	2.8	e-t
	Fathom⟨D⟩	4.0	m-A	3.4	i-x
	La Trobe⟨D⟩	4.0	m-B	4.1	n-C
	GrangeR	4.1	n-D	2.0	a-k
	Spartacus CL⟨D⟩	4.3	o-E	2.0	a-k
	Admiral⟨D⟩	4.6	q-I	2.6	d-r
	Schooner	4.7	r-J	1.7	a-g
	Shepherd⟨D⟩	4.9	t-L	2.8	e-t
	Scope CL⟨D⟩	5.6	x-O	4.9	s-K
	Hindmarsh⟨D⟩	5.7	x-O	3.0	f-u
	Navigator⟨D⟩	6.1	y-Q	2.2	a-l
	Bass⟨D⟩	6.2	A-R	2.2	b-m
	Westminster⟨D⟩	7.0	C-S	3.2	h-v
	Flinders⟨D⟩	7.9	K-U	3.5	j-y
	Fairview⟨D⟩	8.2	K-U	4.4	o-F
	Rosalind⟨D⟩	8.7	N-U	2.6	d-q
	Gairdner⟨D⟩	10.8	S-U	6.1	z-Q
Durum	DBA Aurora⟨D⟩	1.9	a-j	1.1	a
	DBA Lillaroi⟨D⟩	2.3	b-n	2.9	f-t
	Caparoi⟨D⟩	2.8	e-s	1.5	a-e
	190873	3.9	l-A	2.1	a-k
	Jandaroi⟨D⟩	4.6	q-H	3.2	h-w
Bread wheat	Beckom⟨D⟩	4.0	m-A	2.3	b-m
	LRPB Spitfire⟨D⟩	4.3	o-E	4.6	p-G
	Suntop⟨D⟩	5.0	t-M	1.7	a-h
	Sunguard⟨D⟩	5.1	u-M	4.1	n-C
	Kiora⟨D⟩	5.4	v-N	2.7	e-r
	LRPB Viking⟨D⟩	5.6	w-O	4.5	p-G
	QT15046R	6.0	y-P	3.4	i-x
	LRPB Flanker⟨D⟩	6.8	B-S	2.3	b-n
	EGA Gregory⟨D⟩	6.8	B-S	3.6	j-z
	EGA Eaglehawk⟨D⟩	7.2	E-S	6.0	y-Q
	Suntime⟨D⟩	7.4	F-S	5.9	y-P
	LRPB Lancer⟨D⟩	7.5	F-T	1.6	a-f
	Livingston⟨D⟩	7.7	G-T	3.1	g-v
	Sunlamb⟨D⟩	9.5	P-U	7.0	D-S
	Condo⟨D⟩	9.9	Q-U	3.9	l-A
	LPB09-0358	12.1	T-V	7.8	J-U
	LRPB Dart⟨D⟩	12.7	UV	4.6	r-I
	Mitch⟨D⟩	19.2	VW	9.3	O-U
	Elmore CL Plus⟨D⟩	20.7	W	10.1	R-U

Values followed by the same letter are not significantly different ($P = 0.061$) based on transformed data ($\ln(x + 1)$).
Back-transformed values are presented in the table.

Conclusions

Cereal crop and variety choice can significantly affect *Pt* build-up within paddocks, with a 10.8 and 9.6 fold difference in populations between the best and worst variety at this site in 2015 when sown in early May or early June, respectively. In the northern grains region, starting *Pt* populations of below 2.0 *Pt*/g soil are considered low risk; populations between 2.0 and 15.0 *Pt*/g soil are considered medium risk; and above 15.0 *Pt*/g soil is considered high risk for yield loss in intolerant crops or varieties.

Final *Pt* populations were 1.6–4.7 times higher in 14 of the 24 barley entries, in the durum line 190873, and in 12 of the 19 bread wheat entries, when sown in early May compared with sowing in early June. This generally increased the risk for the next crop from a low to a medium level. However, with the two most susceptible bread wheat varieties Mitch⟨D⟩ and Elmore CL Plus⟨D⟩, earlier sowing increased the risk from a medium to high level for the next crop.

Over the past five years there has been a considerable change in grower practice in the northern grains region to sow their winter cereal crops in early May rather than late May or June. This has been primarily driven by the desire to maximise yield potential and use autumn soil moisture for planting. Earlier sowing can also reduce yield loss associated with the dominant soil-borne pathogens in the region: crown rot and *Pt*. However, this trend towards earlier sowing appears to favour higher *Pt* population development with some winter cereal varieties which might exacerbate the negative consequences on following crops and/or varieties in the rotation.

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Crown rot yield loss response curves – Macalister 2015

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Key findings

- Yield loss response curves are an additional tool to help growers in varietal selection decisions to maximise returns where disease is present.
- Variations occurred in the yield response of varieties to crown rot, along with their resistance to this disease.
- The variety Suntop⟮D⟯, although displaying crown rot symptoms similar to that of a susceptible variety, demonstrated a greater ability to maintain yield where disease was present than other varieties that are considered tolerant.
- The selection of varieties based purely on current resistance categories may be overlooking genetics with improved tolerance, such as the variety Suntop⟮D⟯.

Introduction

Production losses due to disease are a major financial constraint to producing cereal crops in Australia, with annual losses in wheat alone estimated at $913 million (Murray & Brennan, 2009; 2010).

Given the demonstrated constraint that disease poses to the grains industry, the Grains Research and Development Corporation (GRDC) funded the yield response curves (YRC) project (DAW00245) with the aim to better understand and quantify potential production losses incurred from foliar, crown and root diseases by developing response curves. Response curves relate a measure of productivity, namely grain yield, to a measure of disease. They are being constructed for a range of varieties differing in resistance levels, across a number of locations and years, for an array of priority pathogens identified to affect the grains industry, both at a regional and national level.

One such pathogen is crown rot, caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*). Crown rot has been identified as affecting winter cereal crops across Australia, with an estimated cost to growers of $97 million annually (Murray & Brennan, 2009). As such, a module of the YRC project, led by the New South Wales Department of Primary Industries, has been dedicated to constructing response curves to explore the impact of crown rot on production losses.

Crown rot infection is characterised by a honey-brown discolouration at the base of infected tillers. Yield loss is related to the expression of whiteheads, which are induced by water and/or temperature stress during flowering and grain-filling. These prematurely ripened spikes contain either no grain or shrivelled grain depending on the timing of stress relative to crop development. All winter cereal crops host the crown rot fungus.

This paper summarises the results from a single experiment conducted near Macalister in Queensland in 2015, presenting response curves for the five wheat varieties considered in the experiment, along with exploring the types of information that can be gathered from the response curves for each variety.

Site details

Location	'Curraweena', Macalister, Qld
Co-operator	Rob Taylor
Sowing date	1 June 2015
Plant population	Target 100 plants/m^2
Fertiliser	250 kg/ha Urea and 40 kg/ha Granulock® 12Z at sowing
Starting Nitrogen	170 kg N/ha to 0.6 m

Rainfall	The growing season rainfall was 121 mm
PreDicta B	5.5 *Pratylenchus thornei*/g soil (medium risk) at sowing (0–30 cm)
Trial design	Randomised complete block design with variety as the main block and inoculum level as the sub-plots; three replications.
Harvest date	2 November 2015

Treatments

Varieties (5)	Four bread wheat varieties (Sunguard$^{\phi}$, Suntop$^{\phi}$, EGA Gregory$^{\phi}$ and LRPB Lincoln$^{\phi}$) and one durum variety (Caparoi$^{\phi}$).
Inoculum rates (6)	Crown rot inoculum, based on sterilised durum grain colonised by at least five different isolates of Fp, was added at sowing at rates of 0, 0.25, 0.5, 1.0, 2.0 and 4.0 g/m of row.

Analysis

The data was analysed using random regression techniques to estimate the yield potential (intercept) and yield response (slope) of each variety in the experiment. Yield potential provides an estimate of a variety's ability to yield in the absence of disease, while the yield response demonstrates the rate at which yield is lost per unit increase in disease pressure.

Results

Varieties differed in both their yield potential where crown rot was absent and yield response, due to crown rot infection (Figure 1). Although named 'curves' the relationship between grain yield and crown rot index was found to be linear in this case.

Using the response curves presented in Figure 1, each variety can be compared for a series of traits. For example, under the highest disease pressure, Suntop$^{\phi}$ still had a 17% (0.7 t/ha) yield loss when compared with the no applied inoculum treatment, while Sunguard$^{\phi}$ lost 12% (0.5 t/ha).

Yield potential

The intercept of the response curve for each variety gives an estimate of the yield potential, or the ability of a variety to yield where crown rot is absent. In this case, it can be seen that Suntop$^{\phi}$ had the greatest yield potential in the Macalister environment in 2015, yielding approximately 4.2 t/ha with no crown rot present. On the other hand, LRPB Lincoln$^{\phi}$ has the lowest yield potential in this environment (approximately 2.5 t/ha). However, the yield potential of LRPB Lincoln$^{\phi}$ in this experiment was severely compromised by the presence of the root lesion nematode, *Pratylenchus thornei* (*Pt*), which was identified as present in medium numbers (5.5 *Pt*/g soil 0–30 cm) using a PreDicta B test before sowing.

Also evident from the response curves is the low background level of crown rot inoculum present at the experimental location, with little disease present in those treatments where no crown rot inoculum was applied. The selection of experimental locations plays a substantial role in the success of these experiments, as high levels of background inoculum and the subsequent infection of plants without the addition of inoculum, prevent the accurate estimation of the yield potential of varieties.

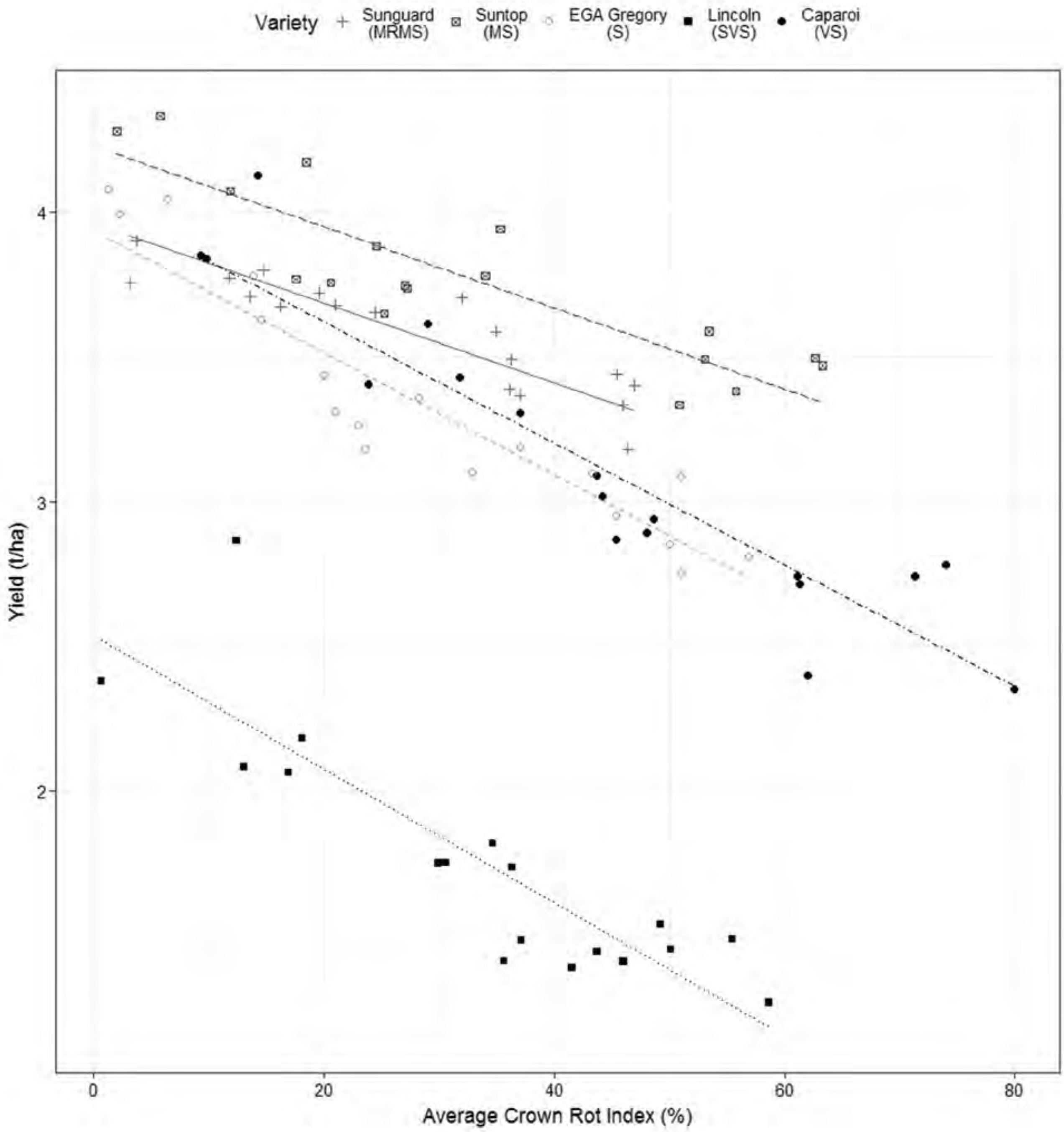

Figure 1. Response curves describing the response in yield of five wheat varieties to crown rot at an experiment near Macalister in 2015. Variety resistance categories provided beneath variety names.

Resistance

The resistance of varieties to disease can also be assessed using response curves. In the case of crown rot, this is achieved through comparing the maximum crown rot index values measured. A variety displaying a greater maximum index is more susceptible to the disease. Using the response curves in Figure 1, Caparoi⦶ displayed the highest crown rot index value (approx. 80%), followed by Suntop⦶ (approx. 63%). Conversely, Sunguard⦶ exhibited the least amount of disease symptoms (maximum value approx. 47%). Comparing the variety rankings according to maximum crown rot index with the resistance categories assigned by the National Variety Testing (NVT) system reveals a high degree of similarity in terms of varietal resistance to crown rot, except for Suntop⦶. Suntop⦶ is rated as a moderately susceptible (MS) variety, however, in this experiment it displayed a maximum crown rot index value second only to the very susceptible (VS) durum wheat, Caparoi⦶. This abnormal behaviour of Suntop⦶ has also been seen in other experiments conducted across the northern grains region (data not shown).

Yield response and tolerance

The yield response of each variety to crown rot is provided by the slope of the response curves; the greater the slope, the more yield is lost per unit increase in crown rot pressure. From a comparison of the responses in Figure 1, the varieties Suntop$^{(\phi)}$ and Sunguard$^{(\phi)}$ are seen to have near equivalent yield responses to the disease, losing approximately 0.01 t/ha per unit increase in the crown rot index. In the case of EGA Gregory$^{(\phi)}$, LRPB Lincoln$^{(\phi)}$ and Caparoi$^{(\phi)}$, the rate of change in yield was doubled, with the varieties losing approximately 0.02 t/ha per unit increase in the crown rot index.

Of particular note is the response of Suntop$^{(\phi)}$. In this case, and at numerous other experiments conducted across the northern grains region (data not shown), the level of disease expressed by Suntop$^{(\phi)}$ is not indicative of the yield losses incurred by the variety. Given the extent of symptoms exhibited, greater yield loss would be expected. This ability to maintain yield in the presence of disease implies the variety has some level of improved tolerance to crown rot.

Yield performance – maximising profitability

The response curves presented in Figure 1 can also be used to determine the point at which growing one variety becomes more profitable than another under crown rot pressure. This comparison involves not only the yields observed, but also the price of grain offered for the different crop types and quality categories. With the higher price recently offered for durum wheat grain relative to bread wheat grain, growers can use the response curves to determine the cross-over point in terms of crown rot pressure where it is still more profitable to produce durum wheat (e.g. Caparoi$^{(\phi)}$), even though it has poorer resistance and tolerance levels relative to some bread wheat varieties (Sunguard$^{(\phi)}$ and Suntop$^{(\phi)}$).

Conclusions

Response curves provide an additional tool that growers can use to select a variety to maximise returns where disease is present. Response curves describing the impact of crown rot on yield were presented in this paper, however, the same approach is being applied by the YRC project to describe yield and grain quality responses to root lesion nematodes, along with foliar diseases of wheat and barley on a national level.

When considering variety selection under crown rot conditions, the response curves presented in Figure 1 pose a number of potential options to growers:

1. Consider chasing the superior yield performance of a variety with a high yield potential that demonstrates improved tolerance to the disease (Suntop$^{(\phi)}$), but could result in more inoculum remaining in the system for future rotations, or
2. Grow a more resistant variety (e.g. MR–MS) that could result in less inoculum in the system (Sunguard$^{(\phi)}$); however, incurring a penalty in terms of lower yield potential.
3. Only target production of varieties with reduced tolerance to crown rot (Caparoi$^{(\phi)}$ and EGA Gregory$^{(\phi)}$) in paddocks that are known to have low inoculum levels (e.g. PreDicta B testing or paddock history).
4. The response curves can be used to determine the point at which it is more profitable to grow one variety or crop type over another under crown rot pressure (e.g. durum wheat vs bread wheat).

Grain quality (protein and screenings) was also measured in this experiment, but the data is not presented here. They are also an important consideration in the above scenarios, especially given that screenings can be exacerbated where crown rot infection is present in some varieties.

This experiment also demonstrates the effect that other soil-borne pathogens can have on varieties' performance. In this case, the root lesion nematode, *Pratylenchus thornei* (*Pt*), severely compromised the performance of LRPB Lincoln$^{(\phi)}$, a variety known to be intolerant of and susceptible to *Pt*. Therefore, when making varietal selection decisions, it is important to select varieties with resistance or tolerance against the target diseases, but also to balance the risk associated with other potential pathogens in the system. PreDicta B offers a useful service to identify and quantify the risks associated with measured levels of inoculum of soil-borne pathogens, such as crown rot and *Pt*, in the cropping system.

Finally, it should be emphasised that variety selection is not the sole solution to crown rot. Even though varieties in this experiment demonstrated improved levels of resistance (Sunguard⦶) or tolerance (Suntop⦶ and Sunguard⦶), which improved their yield performance where crown rot infection was present, significant yield losses still occurred compared with when no crown rot inoculum was applied. Under the highest disease pressure, Suntop⦶ still had a 17% (0.7 t/ha) yield loss when compared with the no applied inoculum treatment, while Sunguard⦶ lost 12% (0.5 t/ha). An integrated approach to managing crown rot is still required to minimise losses from this disease, with selecting varieties with improved tolerance and resistance only one component of an integrated disease management system.

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Fusarium head blight at low levels in the northern grains region in 2016 – cause and implications

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Key findings

- A survey of 80 winter cereal crops across central and northern NSW in 2016 established that low levels (generally <1%) of Fusarium head blight (FHB) were evident with the causal pathogen predominantly being *Fusarium pseudograminearum* (*Fp*).
- This was the crown rot fungus (*Fp*), reminding growers that it does not disappear in a wet season.
- FHB infection caused by *Fp* has a reduced risk for mycotoxin accumulation in infected grain, but could have detrimental impacts on crop establishment if seed is retained for planting.
- Planting *Fusarium*-infected grain can also introduce seed-borne crown rot infection into clean paddocks, negating the rotational benefits associated with growing non-host crops.

Introduction

Above-average rainfall was experienced in many parts of northern NSW in the 2016 winter cropping season. While this was a major driver for increasing crop yield, unfortunately these conditions also favoured the development of a range of diseases. Of particular concern were low levels of head infections in durum and bread wheat crops.

A survey of symptomatic heads and grain samples was conducted in 2016 to determine the various causes and to address concerns around fusarium head blight (FHB) infections. FHB relates to the symptoms of head infection resulting in premature ripening of infected spikelets, generally caused by two fungi *F. graminearum* or *F. pseudograminearum*, following wet weather during flowering and/or grain-fill. White grain disorder, caused by *Eutiarosporella* spp. (formerly Botryosphaeria), produces similar visual symptoms that are not easily distinguished from FHB. These diseases are not uncommon in the northern grains region, with the last widespread occurrence in northern NSW and southern Qld in 2010.

NSW DPI conducted a similar study in 2010 with implications for mycotoxin production based on identification of causal species, issues with sowing infected grain and the potential role of seed treatments investigated. Some of this information will be presented here, as it is still relevant to the situation that occurred in 2016.

Survey details

NSW DPI, with assistance from agronomists and growers, conducted a survey of wheat crops with visible head infections during grain filling to determine the causal fungi. Head and grain symptoms were consistent with either Fusarium head blight or white grain disorder, so laboratory techniques concentrated on recovering these causal pathogens. Representative isolates collected from symptomatic heads or grain were identified to the species level using molecular techniques. Determining the exact causal pathogen has potential consequences for the risk of mycotoxin contamination and end use of affected grain.

Results

Head or grain samples were collected from a total of 80 paddocks from central and northern NSW in 2016 and causal pathogens identified to species. In 66% of cases, FHB was caused by *F. pseudograminearum* (*Fp*) only, 4% by *Fusarium graminearum* (*Fg*) only, 19% were a mixed infection of *Fp* + *Fg*, and 1% (one paddock) had a mixed infection from *Fp* and *F. cerealis* (*Fcer*)(Figure 1).

A total of 4% paddocks had white grain disorder with recovery of Eutiarosporella (*Eut*) only, with a further 4% having a mixed infection of Fp + Eut and 2% (two paddocks) having mixed infection by *Fp* + *Fg* + *Eut* (Figure 1).

Given the increased susceptibility of durum wheat to Fusarium infection, both FHB and crown rot, there was a slight dominance of samples coming from durum crops (54% of paddocks), but symptoms were also evident in many bread-wheat paddocks.

Fusarium pseudograminearum (*Fp*) is the main species usually causing crown rot. Hence, it appears that the low levels of FHB in 66% of paddocks surveyed in 2016 have come from *Fp*-producing spore masses (macroconidia) on the lowest nodes of tillers infected with crown rot. Rain-splash then disperses these spores up the canopy to infect heads at flowering and causes low levels of FHB symptoms in a wet year.

There are two other main species of Fusarium that can cause FHB: *F. graminearum* (*Fg*) and *F. culmorum* (*Fc*). *F. graminearum* has more commonly been associated with FHB in the northern region and has a life stage (perithecia) that is produced on maize, sorghum, grass weeds and winter cereals. The perithecia are full of smaller spores called ascospores, which are air-borne and hence more easily dispersed into wheat heads during flowering than macroconidia.

Fortunately, *Fp* does not readily produce perithecia in the paddock and is not hosted on maize or sorghum. Hence, it lacks an air-borne ascospore stage, which are easily dispersed into heads. A total of 23% of paddocks had FHB infection associated with *Fg*, which was most commonly in a mixed infection with *Fp*. Although *Fc* was not identified in any of the collected samples, another species, *F. cerealis* was identified in a durum sample from Terry Hie Hie in a mixed infection with *Fp* (Figure 1).

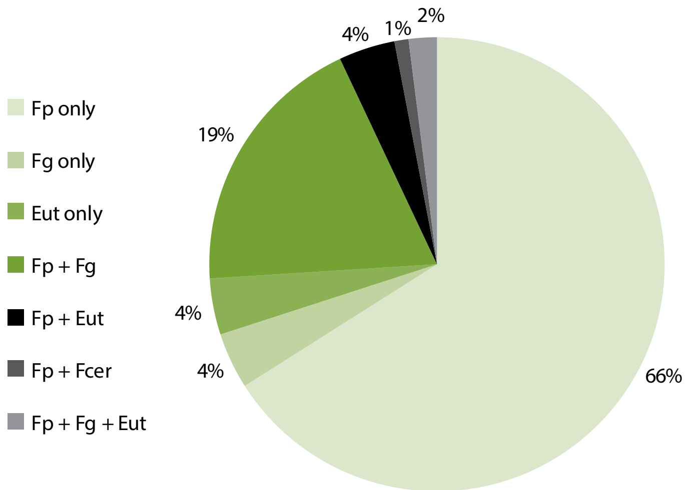

Figure 1. Fungal species associated with head infections in northern NSW in 2016.
Fp = Fusarium pseudograminearum, Fg = Fusarium graminearum, Eut = Eutiarosporella, Fcer = Fusarium cerealis. Values represent the percentage of the 80 paddocks surveyed from which each pathogen was isolated.

Why is identifying the exact causal pathogen important?

Frequent rainfall in winter while cereals are flowering favours FHB infection. On these occasions, if it is *Fp* causing the infection, then the incidence is usually considerably lower than if *Fg* is the causal pathogen. This is due to that lack of an air-borne spore stage (ascospore) with *Fp*, with prolonged wet weather required for *Fp* to first produce spore masses (macroconidia) around lower nodes on infected stems. The macroconidia, although still microscopic, are considerably heavier than ascospores so they require splash dispersal to infect heads during flowering thus limiting their dispersal. In contrast, the ascospore stage in the *Fg* life cycle is not as reliant on moisture for initial maturation of perithecia, which contain the air-borne ascopsores. Rainfall during flowering is simply then required for the ascospores to be released, which wind then more readily disperses into heads during flowering. This was consistent with the very low incidence of infected heads in paddocks in 2016 with most having well below 1% of heads visually infected.

Identification to species level also has implications for potential mycotoxin issues within infected grain. The main mycotoxins produced by Fusarium are deoxynivalenol (DON) and nivalenol (NIV), with NIV being around 10 times more toxic than DON. DON is commonly called vomitoxin in the USA, with regulated limits of 1 ppm (1 mg/kg) in grain for human consumption, 5 ppm for pig feed and 10 ppm for beef/sheep/poultry feed. With *Fg*, DON levels are closely linked to the incidence of visually infected white and pink grains at harvest as mycotoxins are concentrated in these damaged seeds (Sinha & Savard, 1997).

However, grain infected with *Fp* has been shown to accumulate much lower mycotoxin levels than that infected with *Fg* under laboratory conditions (Blaney & Dodman, 2002). This is supported by field sample analysis from a previous occurrence of FHB in Australia in 1984 with Burgess et al. (1987) finding that grain with 38% *Fp* infection only accumulated 0.6 ppm of DON. There are also two different forms (chemotypes) of DON, with 3ADON being half as toxic as the 15ADON form.

Similar research conducted by NSW DPI following an outbreak of FHB in northern NSW and southern Qld in 2010 determined that 92% of 137 *Fp* isolates examined were the 3ADON chemotype, 1.5% were 15ADON, 6.5% were a combination of 15 + 3ADON and none were NIV producers. In contrast, 93% of the 88 *Fg* isolates examined were 15ADON, 3.5% were 3ADON and 3.5% were the NIV chemotype.

Hence, determining which species of Fusarium is causing FHB is important as *Fg* generally produces larger quantities of more toxic forms of mycotoxins (NIV and 15ADON). Conversely, *Fp*, the main cause of FHB in 2010 and again in 2016 in this region, produces considerably lower quantities of a less toxic form of DON (3ADON) only. This has serious implications for sale and end use of the grain produced in these paddocks.

Eutiarosporella spp. (white grain disorder), also causes a head infection with symptoms appearing as premature bleaching of spikelets and production of white grains. These symptoms are hard to distinguish from FHB. However, it has been shown that there are no mycotoxins associated with this pathogen and that grain infected with Eutiarosporella caused no issues when fed to weaner pigs for four weeks (Kopinski & Blaney, 2010). Hence, distinguishing Eutiarosporella infection from FHB has important consequences for the potential end use of affected grain.

Are there issues of retaining Fusarium-infected seed for sowing in 2017?

Grain infected with Fusarium when sown in the following year can cause seedling death, which reduces emergence. Crown rot infection can also be introduced to the base of surviving healthy plants as infected grain is also an inoculum source. Grain infected with Fusarium only occurs as a result of FHB, which is favoured by wet conditions during flowering. Basal crown rot infection alone cannot directly result in grain infection, as the fungus does not grow up the entire stem and into heads within a season.

Additional experimental work at Tamworth in 2011 investigated the effect of grain infection with Fusarium on emergence, and subsequent crown rot infection in surviving plants (seed-borne crown rot infection). Four seed lots naturally infected with varying levels of Fusarium (19–73%) during an outbreak of FHB in 2010 were used in the study.

Grain infected with Fusarium had lower emergence (15–55%) as it caused severe infection in the seedlings and many died, which is commonly called seedling blight. However, the experiment also showed that plants which survived past the seedling-blight stage had also been infected with high levels of crown rot (average 35%). Seed-borne crown rot affects yield in the current crop and introduces infected stubble back into the paddock. Sowing Fusarium-infected seed, therefore, undoes any break-crop benefits that might have been obtained from growing non-host crops (such as chickpea, canola, faba bean, sorghum) in the previous season.

Some seed treatments were shown to improve emergence of Fusarium-infected grain by 10–30%, but had a limited effect on reducing levels of seed-borne crown rot in surviving plants. Ideally, growers should plant wheat seed that is free of Fusarium infection by targeting crops that were not infected with FHB. Grain infected with FHB is usually white and, if prolonged wet conditions occurred during grain-fill, infected grains will take on a pink appearance. However, it should be noted that if any white or pink grains are evident, then the levels of Fusarium infection can be significantly higher than that indicated by visual inspection – laboratory testing is recommended. This is because FHB infections that occur later during grain-fill might not cause any visual seed discolouration.

Conclusions

The low levels of FHB that occurred in bread wheat and durum crops across central and northern NSW in 2016 were predominantly related to *Fp* infection. These infections arose from spore masses produced around lower nodes of crown rot-infected tillers, which were then rain-splashed into heads during flowering.

Mild conditions during spring prevent the expression of crown rot as whiteheads as water supply to the developing head is not limited. Consequently, crown rot infections often go unnoticed in wetter years. The low levels of FHB evident in 2016 could be viewed as the crown rot fungus (*Fp*) reminding growers that it does not go away in a wet season.

Fortunately in 2016, the generally low incidence of FHB infection only resulted in a few instances of issues with harvested grain quality. Hence, the overall economic impact of FHB was relatively minor in 2016. However, if spring conditions in 2016 had been more stressed with limited rainfall and warmer temperatures during grain filling, then significant and widespread losses to crown rot are likely to have occurred. Growers should not be complacent about potential crown rot inoculum levels in 2017.

Avoid sowing winter cereals into paddocks that had FHB in the previous season as they are likely to represent a high risk for crown rot infection for the following year. All durum wheat varieties have increased susceptibility to Fusarium infection, both FHB and crown rot, hence durum production should be targeted to low-risk paddocks, preferably based on stubble or PreDicta B testing.

Growers who noticed or suspect that they had FHB or white grain disorder should get their planting seed tested to determine infection levels before sowing that seed in the next season.

This information can be used to guide appropriate seed treatment options or to source alternative cleaner seed with lower infection levels if required. This should be the preferred option compared with sowing seed with unknown Fusarium levels which, if moderately infected, will result in poor establishment and introduce significant crown rot levels into paddocks. This will compromise rotational benefits that might have been achieved by previously growing non-host crops.

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Regional crown rot management – Trangie 2016

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Key findings

- Yield loss from crown rot ranged from not significant in the bread wheat variety LRPB Relianⓓ up to 16.9% in the barley variety Compassⓓ.
- Bread wheat variety choice affected yield in the presence of high levels of crown rot infection with three entries being between 0.45 t/ha and 0.85 t/ha higher yielding than the susceptible bread wheat variety EGA Gregoryⓓ.
- Grain protein levels were low across the site (mean of 9.8%) and varied from 8.7% in Mitchⓓ up to 10.6% in LRPB Spitfireⓓ Crown rot infection did not affect protein levels in any entry.
- Crown rot infection caused a small (1–4%), but significant increase in screenings in the barley variety La Trobeⓓ and all of the 13 bread wheat entries.

Introduction

Crown rot (CR), caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to winter cereal production in the northern grains region. 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.

This experiment was one of 11 conducted by NSW DPI in 2016 across central/northern NSW extending into southern Qld; to examine the impact of crown rot on the yield and quality of four barley, three durum and 13 bread wheat varieties.

Site details

Location	Trangie Agricultural Research Centre, Trangie.
Sowing date	19 May 2016
Fertiliser	80 kg/ha Granulock Z Extra (Sapphire) (11.5% N 19.8% P 5.4% S) at sowing.
Starting nitrogen (N)	170.8 kg N/ha (0–120 cm)
Starting soil water	~60–70 mm plant available soil water (based on a 25% fallow efficiency) (0–120 cm)
Rainfall	The growing season rainfall was 379 mm
PreDicta B	Nil *Pratylenchus thornei*, nil *P. neglectus* and 2.0 log *Fusarium* DNA/g soil (medium crown rot risk) at sowing (0–15 cm)
Harvest date	24 November 2016

Treatments

Varieties (20)

- Four barley varieties: Commanderⓓ, Compassⓓ, La Trobeⓓ and Spartacusⓓ.
- Three durum varieties: Jandaroiⓓ and Lillaroiⓓ plus the numbered line 190873.
- Thirteen bread wheat varieties: EGA Gregoryⓓ, LRPB Flankerⓓ, Beckomⓓ, Coolahⓓ, Sunmateⓓ, LRPB Lancerⓓ, LRPB Reliantⓓ, LRPB Gauntletⓓ, LRPB Spitfireⓓ, Mitchⓓ, Suntopⓓ and Sunguardⓓ; (listed in order of increasing resistance to crown rot) plus one numbered line LPB12-0494.

Pathogen treatment

Added or no added crown rot at sowing using sterilised durum grain colonised by at least five different isolates of *Fp* at a rate of 2.0 g/m of row at sowing.

Results

Yield

In the no added CR treatment, yield ranged from 3.81 t/ha in the durum variety DBA Lillaroi$^{\phi}$ up to 5.98 t/ha in the bread wheat variety Beckom$^{\phi}$ (Table 1). Only the bread wheat variety LRPB Reliant$^{\phi}$ did not suffer significant yield loss under high levels of crown rot infection (added CR). In the remaining entries, yield loss ranged from 5.4% in the bread wheat variety LRPB Lancer$^{\phi}$ (0.26 t/ha) up to 16.9% in the barley variety Compass$^{\phi}$ (0.74 t/ha).

Three of the barley varieties (except Commander$^{\phi}$), all three durum entries and the bread wheat variety LRPB Flanker$^{\phi}$ were significantly lower yielding than EGA Gregory$^{\phi}$ under high crown rot infection (added CR). Three bread wheat varieties – Beckom$^{\phi}$ (by 0.85 t/ha), Coolah$^{\phi}$ (by 0.57 t/ha) and Mitch$^{\phi}$ (by 0.45 t/ha) – were the only entries higher yielding than EGA Gregory$^{\phi}$ under high levels of crown rot infection (added CR; Table 1). The remaining nine bread wheat entries produced yields equivalent to EGA Gregory$^{\phi}$ in the added CR treatment.

Table 1. Yield and grain quality of varieties with no added and added crown rot – Trangie 2016.

Crop	Variety	Yield (t/ha)		Protein	Screenings (%)	
		No added CR	Added CR	(%)	No added CR	Added CR
Barley	Commander	4.93	4.52	9.0	2.1	1.7
	Spartacus	5.01	4.28	9.8	2.7	3.2
	La Trobe	4.34	4.05	9.6	3.0	4.7
	Compass	4.36	3.62	9.2	1.7	2.2
Durum	Jandaroi	4.12	3.88	10.0	4.1	5.6
	190873	3.95	3.53	10.5	4.8	5.7
	DBA Lillaroi	3.81	3.48	10.0	6.0	6.8
Bread wheat	Beckom	5.98	5.45	9.3	4.2	6.0
	Coolah	5.45	5.17	9.4	7.4	9.9
	Mitch	5.48	5.05	8.7	7.7	9.7
	LRPB Reliant	4.86	4.73	9.6	9.8	13.5
	LPB12-0494	4.94	4.64	10.1	7.6	11.5
	Sunmate	4.93	4.63	9.9	10.6	14.6
	LRPB Lancer	4.86	4.60	10.4	6.4	10.0
	Suntop	5.10	4.60	10.0	5.1	8.7
	EGA Gregory	5.25	4.60	9.5	10.6	12.5
	LRPB Spitfire	4.88	4.58	10.6	5.9	9.8
	LRPB Gauntlet	4.70	4.43	10.1	7.3	10.9
	Sunguard	4.72	4.42	9.9	7.3	9.2
	LRPB Flanker	4.98	4.24	9.6	9.2	12.3
Site mean		4.83	4.42	9.8	6.2	8.4
CV (%)		3.0		3.7	13.9	
l.s.d.		0.227		0.42	1.65	
P value		0.002		<.001	0.001	

Grain quality

Protein levels were low at this site in 2016 and ranged between 8.7% (Mitch$^{\phi}$) up to 10.6% (LRPB Spitfire$^{\phi}$; Table 1). Crown rot infection (added CR) did not significantly affect grain protein levels in any of the entries at this site in 2016.

In the no added CR treatment, screening levels ranged from 1.7% in the barley variety Compass$^{\phi}$ up to 10.6% in the bread wheat varieties Sunmate$^{\phi}$ and EGA Gregory$^{\phi}$ (Table 1).

Screening levels were increased by around 1–4% in the added CR treatment, with the barley variety La Trobe and all 13 bread wheat entries (Table 1). In the remaining entries, there was no significant difference in the level of screenings between the no added CR and added CR treatments. In the added CR treatment, screening levels ranged from 1.7% in the barley variety Commander⁽ᵖ⁾ up to 14.6% in the bread wheat variety Sunmate⁽ᵖ⁾ (Table 1).

Conclusions

Three of the bread wheat varieties (Mitch⁽ᵖ⁾, Coolah⁽ᵖ⁾ and Beckom⁽ᵖ⁾) provided a 10–19% yield benefit over growing the susceptible bread wheat variety EGA Gregory⁽ᵖ⁾ under high levels of crown rot infection at Trangie in 2016. This could have maximised profit in this growing season but will **not** reduce inoculum levels for subsequent crops, because all winter cereal varieties are susceptible to crown rot infection. Winter cereal crop and variety choice is therefore not the sole solution to crown rot, but rather just one element of an integrated management strategy to limit losses from this disease.

Acknowledgements

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Impact of common root rot and crown rot on wheat yield – Tamworth 2016

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Key findings

- A medium level of common root rot infection reduced the yield of LRPB Gauntlet[⚐] by 5% with a high level of infection resulting in 13% yield loss.
- The expression of crown rot was reduced in 2016 due to the wet seasonal conditions. The medium level of infection did not significantly reduce the yield of LRPB Gauntlet[⚐], but a high level of infection caused 9% yield loss.
- Combined infection with both pathogens – common root rot and crown rot – further exacerbated yield loss, which equated to 23% with a high level of inoculum of both pathogens.
- The effect from a mild, wet season on reducing the extent of yield loss caused by either of these two pathogens appears to be more pronounced with crown rot than common root rot.

Introduction

Crown rot, caused by the stubble-borne fungus *Fusarium pseudograminearum* (*Fp*), is a significant disease of winter cereals across the northern grains region. Considerable research has established its impact on the yield of commonly grown wheat, barley and durum varieties across environments and seasons.

Common root rot, caused by the fungus *Bipolaris sorokiniaina* (*Bs*), is a widespread pathogen of winter cereal crops throughout Australia and is often found in association with crown rot. *Bs* survives not only as mycelium inside winter cereal and grass weed residues, but also has a thick-walled spore structure (conidium) that allows it to survive in the soil for around two years. *Bs* infects the sub-crown internode where it causes complete or partial dark brown to black tissue discolouration.

Symptoms of common root rot are fairly indistinct in the paddock, with severely infected plants having reduced thrift and decreased tiller numbers. Common root rot is generally considered a less significant pathogen of winter cereals across the northern grains region than crown rot or root lesion nematodes. A 15% yield loss from common root rot under severe levels of infection is often quoted, but there is limited published data to support this value.

The prevalence of common root rot has increased across the region in recent seasons, usually associated with deeper sowing where growers are forced to moisture seek at planting as a result of diminishing soil moisture at the surface. This practice unfortunately lengthens the sub-crown internode, which appears to be exacerbating common root rot infection.

A similar trial conducted at Tamworth in 2015 found that common root rot reduced the yield of LRPB Gauntlet[⚐] by 11% and 20% with a medium or high level of infection, respectively. However, crown rot infection resulted in around double the extent of yield loss, 23% and 41% with a medium or high level of infection, respectively. Combined infection with both pathogens further exacerbated yield loss in 2015, which equated to 31% and 52% with a medium or high level of inoculum of both pathogens, respectively.

This study aimed to compare the relative impact of common root rot and crown rot on wheat yield and determine if mixed infection exacerbates losses in a second season.

Site details

Location	Tamworth Agricultural Institute
Sowing date	16 June 2016
Plant population	Target 100 plants/m^2
Fertiliser	100 kg/ha Urea and 50 kg/ha Granulock® 12Z at sowing
Rainfall	The growing season rainfall was 431 mm

Harvest date	12 December 2016

Treatments

Varieties

One variety, LRPB Gauntlet⁽ᵗʰ⁾, which is rated moderately susceptible-susceptible (MS–S) to both common root rot and crown rot.

Pathogen treatments

Added common root rot inoculum at sowing using sterilised durum grain colonised by at least three different isolates of *Bs* at three rates to create nil (0 g/m row), medium (1.0 g/m row) or high (2.0 g/m row) infection levels.

Added crown rot inoculum at sowing using sterilised durum grain colonised by at least five different isolates of *Fp* at three rates to create nil (0 g/m row), medium (1.0 g/m row) or high (2.0 g/m row) infection levels.

Different inoculum rates of the two pathogens added alone or in combination at sowing with viable LRPB Gauntlet⁽ᵗʰ⁾ seed with four replicates of each treatment.

A control (uninoculated) nil treatment consisted of nil (0 g/m row) of both pathogens.

Results

A medium level of common root rot (Bipolaris) inoculum reduced the yield of LRPB Gauntlet⁽ᵗʰ⁾ by 0.22 t/ha (5%), with a high level of inoculum reducing yield by 0.59 t/ha (13%) compared with plants not inoculated with either fungal pathogen (Figure 1).

A medium level of crown rot (*Fusarium*) inoculum did not significantly reduced the yield of LRPB Gauntlet⁽ᵗʰ⁾, but a high level of inoculum reduced yield by 0.41 t/ha (9%) compared with plants not inoculated with either fungal pathogen (Figure 1).

A medium level of inoculum of both common root rot and crown rot reduced the yield of LRPB Gauntlet⁽ᵗʰ⁾ by 0.33 t/ha (7%), with a high level of inoculum of both pathogens reducing yield by 1.05 t/ha (23%). The yield effect from a combination of inoculation with both pathogens was significantly higher than inoculation with either pathogen alone at the high inoculum rates (Figure 1).

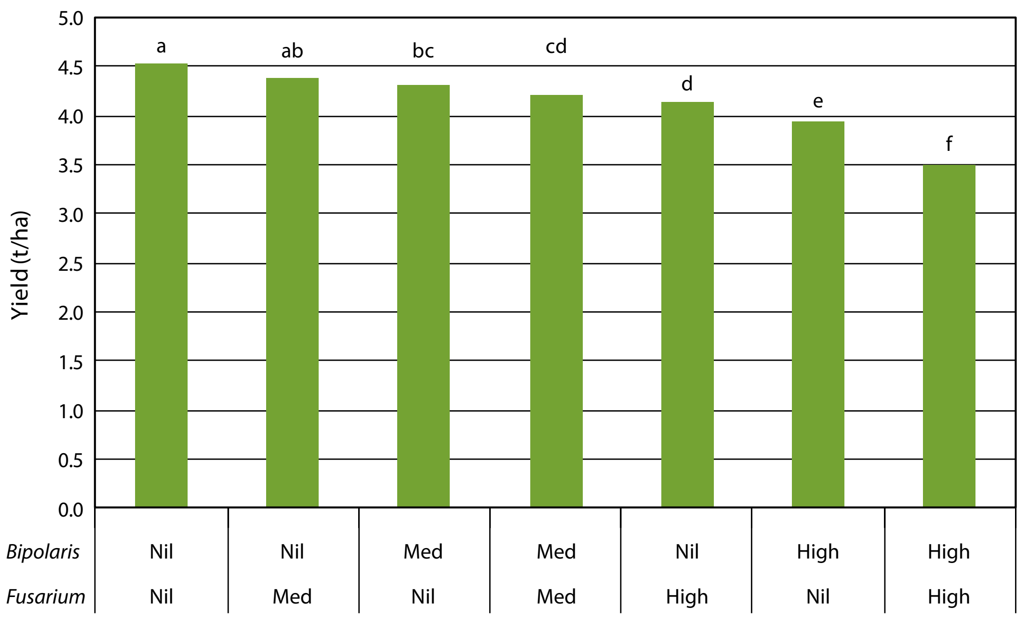

Figure 1. Impact of varying levels of Fusarium (crown rot) and Bipolaris (common root rot) inoculum on the yield of LRPB Gauntlet⁽ᵗʰ⁾ – Tamworth 2016. Bars with the same letter are not significantly different (*P* = 0.05).

Conclusions

Crown rot infection was shown to cause less yield loss (not significant to 9%) than common root rot (5–13%) in the MS–S bread wheat variety LRPB Gauntlet⁽ᴰ⁾ in 2016. This was vastly different to the results from the same experiment conducted in 2015, where crown rot (23–41%) caused around double the extent of yield loss compared with common root rot (11–20%). The 2016 season was considerably wetter (431 mm in-crop rainfall) than the 2015 season (286 mm in-crop rainfall), which limited the expression of crown rot. The yield loss associated with common root rot infection was also reduced in 2016 compared with 2015, but not to the same extent as with crown rot.

Visual symptoms associated with common root rot infection are less obvious than those associated with the expression of crown rot in a drier season. Hence, common root rot is generally considered a less important soil-borne pathogen of winter cereal crops than crown rot. However, common root rot is still a significant pathogen of wheat, which appears to being increasing in prevalence in the northern grains region in association with deeper seeding to capture diminishing soil moisture in the surface layer at sowing.

Although common root rot infection generally causes lower levels of yield loss compared with crown rot infection, it still appears to occur in both drier (11–20% in 2015) and wetter (5–13% in 2016) seasons. The potential importance of common root rot in the farming system is further intensified by its interaction with crown rot, especially in drier seasons, with yield losses appearing to be exacerbated by the presence of both pathogens. Common root rot infects the sub-crown internode, which is believed to reduce the efficacy of the primary root system. Yield loss from crown rot is known to be associated with increased moisture/evapotranspiration stress during grain filling, which was limited by wet seasonal conditions in 2016. A reduction in the ability of the primary root system to extract soil moisture at depth, as a result of common root rot infection, appears to increase the expression of crown rot and hence yield loss from these diseases in drier seasons.

Integrated management strategies aimed at reducing effects from crown rot should also consider their effect on common root rot and the interaction between these two pathogens.

Acknowledgements

This experiment was part of the project *Northern NSW integrated disease management* (DAN00176; 2013–18), with joint investment by NSW DPI and GRDC. Assistance provided by Robyn Shapland, Tim O'Brien, Patrick Mortell, Finn Fensbo, Chyrstal Fensbo and Carla Lombardo (NSW DPI) is greatly appreciated.

Regional crown rot management – Garah 2016

Steven Simpfendorfer and Robyn Shapland
NSW DPI, Tamworth

Key findings

- Yield loss from crown rot ranged from not significant in the barley varieties Spartacus$^{\phi}$ and Commander$^{\phi}$ up to around 20% in the barley variety Compass$^{\phi}$ and bread wheat varieties EGA Gregory$^{\phi}$ and LRPB Flanker$^{\phi}$.
- Bread wheat variety choice affected yield in the presence of high levels of crown rot infection with five entries being between 0.32 t/ha to 0.57 t/ha higher yielding than the susceptible bread wheat variety EGA Gregory$^{\phi}$.
- Grain protein levels varied from 11.3% in Mitch$^{\phi}$ up to 14.9% in LRPB Spitfire$^{\phi}$. Crown rot infection did not affect protein levels in any entry.
- Crown rot infection increased the level of screenings in all four barley varieties and the two bread wheat varieties Sunmate$^{\phi}$ and LRPB Reliant$^{\phi}$.

Introduction

Crown rot (CR), caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to winter cereal production in the northern grains region. 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.

This experiment was one of 11 conducted by NSW DPI in 2016 across central/northern NSW extending into southern Qld; to examine the impact of crown rot on the yield and quality of four barley, three durum and 13 bread wheat varieties.

Site details

Location	'Miroobil', Garah
Co-operator	Andrew and Bill Yates
Sowing date	10 June 2016
Fertiliser	60 kg/ha Urea and 60 kg/ha Granulock 12Z (treated with 400 mL/ha of flutriafol) at sowing
Starting nitrogen	167 kg N/ha to 120 cm
Starting soil water	40 mm plant available soil water (0–120 cm)
Rainfall	The growing season rainfall was 174 mm
PreDicta B	1.7 *Pratylenchus thornei*/g soil (low risk), nil *P. neglectus* and nil crown rot at sowing (0–15 cm)
Harvest date	23 November 2016

Treatments

Varieties (20)

- Four barley varieties: Commander$^{\phi}$, Compass$^{\phi}$, La Trobe$^{\phi}$ and Spartacus$^{\phi}$.
- Three durum varieties: Jandaroi$^{\phi}$ and Lillaroi$^{\phi}$ plus the numbered line 190873.
- Thirteen bread wheat varieties: EGA Gregory$^{\phi}$, LRPB Flanker$^{\phi}$, Beckom$^{\phi}$, Coolah$^{\phi}$, Sunmate$^{\phi}$, LRPB Lancer$^{\phi}$, LRPB Reliant$^{\phi}$, LRPB Gauntlet$^{\phi}$, LRPB Spitfire$^{\phi}$, Mitch$^{\phi}$, Suntop$^{\phi}$ and Sunguard$^{\phi}$; (listed in order of increasing resistance to crown rot) plus one numbered line LPB12-0494.

Pathogen treatment

Added or no added crown rot at sowing using sterilised durum grain colonised by at least five different isolates of *Fp* at a rate of 2.0 g/m of row at sowing.

Results

Yield

In the no added CR treatment, yield ranged from 3.54 t/ha in the barley variety Commander$^{\phi}$ up to 5.61 t/ha in the bread wheat variety LRPB Flanker$^{\phi}$ (Table 1).

Only two of the barley varieties, Spartacus$^{\phi}$ and Commander$^{\phi}$, did not suffer significant yield loss under high levels of crown rot infection (added CR). In the remaining entries, yield loss ranged from 7.6% in the bread wheat variety Mitch$^{\phi}$ (0.40 t/ha) up to 21.6% in the barley variety Compass$^{\phi}$ (0.93 t/ha).

All four barley varieties, the durum variety DBA Lillaroi$^{\phi}$ and the bread wheat variety LRPB Spitfire$^{\phi}$ were lower yielding than EGA Gregory$^{\phi}$ under high crown rot infection (added CR). The remaining durum entries and six of the bread wheat varieties (LRPB Gauntlet$^{\phi}$, Sunguard$^{\phi}$, LRPB Reliant$^{\phi}$, LRPB Lancer$^{\phi}$, LRPB Flanker$^{\phi}$ and Beckom$^{\phi}$) all produced yields equivalent to EGA Gregory$^{\phi}$ in the added CR treatment (Table 1).

The bread wheat entries Sunmate$^{\phi}$ (0.57 t/ha), Mitch$^{\phi}$ (0.49 t/ha), LPB12-0494 (0.36 t/ha), Suntop$^{\phi}$ (0.34 t/ha) and Coolah$^{\phi}$ (0.32 t/ha) were all higher yielding than EGA Gregory$^{\phi}$ under high levels of crown rot infection (added CR; Table 1).

Grain quality

Protein levels were relatively high at this site in 2016 and ranged between 11.3% (Mitch$^{\phi}$) up to 14.9% (LRPB Spitfire$^{\phi}$; Table 1). Crown rot infection (added CR) did not significantly affect grain protein levels in any of the entries at this site in 2016.

In the no added CR treatment, screening levels ranged from 1.9% in the bread wheat variety LRPB Lancer$^{\phi}$ up to 7.9% in the barley variety La Trobe$^{\phi}$ (Table 1).

Screening levels were increased in the added CR treatment, with all four barley varieties and two of the bread wheat varieties Sunmate$^{\phi}$ and LRPB Reliant$^{\phi}$ by between 1.7 to 5.6%. In the remaining entries there was no significant difference in the level of screenings between the no added CR and added CR treatments. In the added CR treatment, screening levels ranged from 2.9% in the bread wheat variety LRPB Lancer$^{\phi}$ up to 10.7% in the barley variety La Trobe$^{\phi}$ (Table 1).

Table 1. Yield and grain quality of varieties with no added and added crown rot – Garah 2016.

Crop	Variety	Yield (t/ha)		Protein	Screenings (%)	
		No added CR	Added CR	(%)	No added CR	Added CR
Barley	La Trobe	4.63	4.09	13.9	7.9	10.7
	Spartacus	4.35	4.07	14.5	3.8	9.4
	Compass	4.29	3.36	13.8	3.4	5.3
	Commander	3.54	3.24	14.1	5.4	7.9
Durum	Jandaroi	5.17	4.64	13.0	2.8	4.1
	190873	5.21	4.52	12.9	2.7	3.5
	DBA Lillaroi	4.90	4.04	14.2	4.5	5.8
Bread wheat	Sunmate	5.52	4.97	12.1	4.7	6.4
	Mitch	5.29	4.89	11.3	3.4	4.7
	LPB12-0494	5.31	4.76	12.1	5.9	7.2
	Suntop	5.13	4.74	12.2	3.9	4.5
	Coolah	5.52	4.72	11.9	2.2	3.2
	LRPB Gauntlet	5.19	4.68	12.5	4.0	5.4
	Sunguard	5.09	4.61	12.6	3.8	4.8
	LRPB Reliant	5.43	4.52	12.0	6.4	8.7
	LRPB Lancer	5.15	4.50	13.4	1.9	2.9
	LRPB Flanker	5.61	4.47	12.4	3.2	4.2
	EGA Gregory	5.52	4.40	12.4	3.3	4.5
	Beckom	5.37	4.33	12.4	3.8	5.3
	LRPB Spitfire	4.43	3.93	14.9	3.6	5.1
Site mean		5.03	4.37	12.9	4.0	5.7
CV (%)		4.1		1.8	19.5	
l.s.d.		0.310		0.27	1.54	
P value		<.001		<.001	0.019	

Conclusions

Cereal crop and variety choice provided a 7–13% yield benefit over growing the susceptible bread wheat variety EGA Gregory⊕ under high levels of crown rot infection at Garah in 2016. This could have maximised profit in this growing season, but will **not** reduce inoculum levels for subsequent crops because all winter cereal varieties are susceptible to crown rot infection. Winter cereal crop and variety choice is therefore **not** the sole solution to crown rot, but rather just one element of an integrated management strategy to limit losses from this disease.

Acknowledgements

This experiment was part of the project *National crown rot epidemiology and management program* (DAN00175) with joint investment by NSW DPI and GRDC. Thanks to Andrew and Bill Yates for providing the trial site and Rick Graham, Jim Perfrement, Mick Dal Santo, Stephen Morphett (NSW DPI) for sowing, maintaining and harvesting the trial. Thanks to Chrystal Fensbo (NSW DPI) for grain quality assessments and to Jason Lowien (GrainCorp) for use of an NIR machine to determine grain protein levels.

Regional crown rot management – Tamarang 2016

Steven Simpfendorfer and Robyn Shapland
NSW DPI, Tamworth

Key findings

- Yield loss from crown rot ranged from not significant in five of the bread wheat varieties, the barley variety Commander$^{\phi}$ and the durum variety Jandaroi$^{\phi}$ up to 12.9% in the bread wheat variety EGA Gregory$^{\phi}$.
- The recently released durum variety DBA Lillaroi$^{\phi}$ produced a protein level of 15% which was over 1% higher than the two other durum entries Jandaroi$^{\phi}$ and 190873.
- Crown rot infection did not significantly impact on the level of screenings in any of the entries due to limited expression under the wet seasonal conditions at this site in 2016. However, genetic differences were evident with screening levels which ranged from 3.2% in the durum line 190873 up to 17.6% in the bread wheat variety Beckom$^{\phi}$.

Introduction

Crown rot (CR) caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to the production of winter cereals in the northern grains region. 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.

This experiment was one of 11 conducted by NSW DPI in 2016 across central/northern NSW extending into southern Qld; to examine the impact of crown rot on the yield and quality of four barley, three durum and 13 bread wheat varieties.

Site details

Location	'The Point', Tamarang
Co-operator	David Ronald
Sowing date	17 June 2016
Fertiliser	60 kg/ha Granulock 12Z (treated with 400 mL/ha of flutriafol) at sowing
Starting N	250 kg N/ha to 120 cm
PAWC	246 mm plant available soil water (0–120 cm)
Rainfall	The growing season rainfall was 472 mm
PreDicta B	Nil *Pratylenchus thornei*, nil *P. neglectus* and nil crown rot at sowing (0–15 cm)
Harvest date	14 December 2016

Treatments

Varieties (20)

- Four barley varieties: Commander$^{\phi}$, Compass$^{\phi}$, La Trobe$^{\phi}$ and Spartacus$^{\phi}$.
- Three durum varieties: Jandaroi$^{\phi}$ and Lillaroi$^{\phi}$ plus the numbered line 190873.
- Thirteen bread wheat varieties: EGA Gregory$^{\phi}$, LRPB Flanker$^{\phi}$, Beckom$^{\phi}$, Coolah$^{\phi}$, Sunmate$^{\phi}$, LRPB Lancer$^{\phi}$, LRPB Reliant$^{\phi}$, LRPB Gauntlet$^{\phi}$, LRPB Spitfire$^{\phi}$, Mitch$^{\phi}$, Suntop$^{\phi}$ and Sunguard$^{\phi}$; (listed in order of increasing resistance to crown rot) plus one numbered line LPB12-0494

Pathogen treatment

Added or no added crown rot at sowing using sterilised durum grain colonised by at least five different isolates of *Fp* at 2.0 g/m of row at sowing.

Results

Yield

In the no added CR treatment, yield ranged from 5.11 t/ha in the bread wheat variety Sunmate[ɸ] up to 7.38 t/ha in the durum variety DBA Lillaroi[ɸ] (Table 1).

The barley variety Commander[ɸ], durum variety Jandaroi[ɸ] and five of the bread wheat entries (LPB12-0494, LRPB Gauntlet[ɸ], LRPB Lancer[ɸ], Sunguard[ɸ] and LRPB Spitfire[ɸ]) did not suffer significant yield loss under high levels of crown rot infection (added CR). In the remaining entries, yield loss ranged from 4.2% in the bread wheat variety LRPB Reliant[ɸ] (0.26 t/ha) up to 12.9% in the bread wheat variety EGA Gregory[ɸ] (0.77 t/ha).

Only the bread wheat variety Sunmate[ɸ] was lower yielding than EGA Gregory[ɸ] under high crown rot infection (added CR). The barley variety La Trobe[ɸ] and two bread wheat varieties (Sunguard[ɸ] and LRPB Spitfire[ɸ]) all produced yields equivalent to EGA Gregory[ɸ] in the added CR treatment (Table 1).

All three durum entries produced yields higher than EGA Gregory. The bread wheat entries Mitch[ɸ] (0.87 t/ha), Coolah[ɸ] (0.79 t/ha), LRPB Reliant[ɸ] (0.70 t/ha), Suntop[ɸ] (0.63 t/ha), LRPB Flanker[ɸ] (0.61 t/ha), Beckom[ɸ] (0.56 t/ha), LPB12-0494 (0.51 t/ha), LRPB Gauntlet[ɸ] (0.36 t/ha) and LRPB Lancer[ɸ] (0.29 t/ha) were all higher yielding than EGA Gregory[ɸ] under high levels of crown rot infection (added CR; Table 1). The barley entries Spartacus[ɸ] (0.54 t/ha), Commander[ɸ] (0.49 t/ha) and Compass[ɸ] (0.49 t/ha) were also higher yielding than EGA Gregory[ɸ] in the added CR treatment.

Table 1. Yield and grain quality of varieties with no added and added crown rot – Tamarang 2016.

Crop	Variety	Yield (t/ha)		Protein	Screenings
		No added CR	Added CR	(%)	(%)
Barley	Spartacus	6.43	5.75	14.9	8.2
	Commander	5.83	5.70	14.8	9.3
	Compass	6.21	5.70	15.7	6.1
	La Trobe	6.13	5.39	15.0	10.4
Durum	Jandaroi	7.28	7.05	13.8	3.8
	DBA Lillaroi	7.38	6.85	15.0	3.5
	190873	7.08	6.63	13.9	3.2
Bread wheat	Mitch	6.53	6.08	12.1	8.5
	Coolah	6.36	6.00	12.1	5.7
	LRPB Reliant	6.17	5.91	12.3	7.9
	Suntop	6.14	5.84	12.4	10.2
	LRPB Flanker	6.29	5.82	12.9	7.0
	Beckom	6.34	5.77	12.5	17.6
	LPB12-0494	5.89	5.72	12.1	9.3
	LRPB Gauntlet	5.78	5.57	12.7	8.9
	LRPB Lancer	5.73	5.50	13.1	8.6
	Sunguard	5.34	5.22	12.5	11.6
	EGA Gregory	5.98	5.21	12.6	7.5
	LRPB Spitfire	5.34	5.10	14.0	13.7
	Sunmate	5.11	4.81	12.5	10.8
Site mean		6.17	5.78	13.3	8.6
CV (%)		2.5		2.1	14.8
l.s.d.		0.246		0.32	1.46
P value		0.001		<.001	<.001

Grain quality

Protein levels were relatively high at this site in 2016, which is likely a result of the high starting soil nitrogen levels. Protein levels in the bread wheat entries varied from 12.1% in Mitch$^{\phi}$, Coolah and LPB12-0494 up to 14.0% in LRPB Spitfire$^{\phi}$ (Table 1). Crown rot infection (added CR) did not significantly affect grain protein levels in any of the entries at this site in 2016. The recently released durum variety DBA Lillaroi$^{\phi}$ achieved 1.1–1.2% higher grain protein levels (15.0%) than the other two durum entries in this experiment.

Crown rot infection did not significantly affect the level of screenings in any of the entries at this site in 2016. However, genetic differences were evident with screening levels ranging from 3.2% in the durum line 190873 up to 17.6% in the bread wheat variety Beckom$^{\phi}$ (Table 1).

Conclusions

Cereal crop and variety choice affected yield in the absence and presence of crown rot infection, which differed by 2.26 t/ha and 2.24 t/ha, respectively between the best and worst entries. The three durum entries were higher yielding relative to bread wheat and barley entries in both the added CR and no added CR treatments at this site in 2016. This was likely due to seasonal conditions (near full soil water profile at sowing plus 472 mm of in-crop rainfall), which limited crown rot expression.

Cereal crop and variety choice still provided a 9% to 35% yield benefit over growing the susceptible bread wheat variety EGA Gregory$^{\phi}$ under high levels of crown rot infection at Tamarang on the Liverpool Plains in 2016. This can maximise profit in the current season but will **not** reduce inoculum levels for subsequent crops, because all winter cereal varieties are susceptible to crown rot infection. Winter cereal crop and variety choice is therefore **not** the sole solution to crown rot, but rather just one element of an integrated management strategy to limit losses from this disease.

Acknowledgements

This research was part of the project *National crown rot epidemiology and management program* (DAN00175), with joint investment by NSW DPI and GRDC. Thanks to David Ronald for providing the trial site and Rick Graham, Jim Perfrement, Mick Dal Santo, Stephen Morphett (NSW DPI) for sowing, maintaining and harvesting the trial. Thanks to Chrystal Fensbo (NSW DPI) for grain quality assessments and to Jason Lowien (GrainCorp) for use of an NIR machine to determine grain protein levels.

Regional crown rot management – Bullarah 2016

Steven Simpfendorfer and Robyn Shapland
NSW DPI, Tamworth

Key findings

- Yield loss from crown rot ranged from 7.6% in the bread wheat variety LRPB Spitfire⁽ᵈ⁾ up to 29.1% in the barley variety Commander⁽ᵈ⁾.
- Bread wheat variety choice affected yield in the presence of high levels of crown rot infection with nine entries being 0.30 t/ha to 1.33 t/ha higher yielding than the susceptible bread wheat variety EGA Gregory⁽ᵈ⁾.
- Grain protein levels varied from 12.0% in Mitch⁽ᵈ⁾ up to 15.8% in the recently released durum variety DBA Lillaroi⁽ᵈ⁾. Crown rot infection did not affect any grain protein level in any entry.
- Screening levels varied from 2.2% in the barley variety Compass⁽ᵈ⁾ up to 9.5% in the bread wheat line LPB12-0494.
- Crown rot infection did not affect screening levels in any entry.

Crop protection

Introduction

Crown rot (CR), which is caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to winter cereal production in the northern grains region. Cereal varieties differ in their resistance to crown rot, which can significantly affect their relative yield in the presence of this disease.

This experiment was one of 11 conducted by NSW DPI in 2016 across central/northern NSW extending into southern Qld; to examine the effect of crown rot on the yield and quality of four barley, three durum and 13 bread wheat varieties.

Site details

Location	'Dunbar', Bullarah
Co-operator	Brad Coleman
Sowing date	25 May 2016
Fertiliser	250 kg/ha Urea and 60 kg/ha Granulock 12Z (treated with 400 mL/ha of flutriafol) at sowing
Starting nitrogen	111 kg N/ha to 120 cm
Starting soil water	95 mm plant available soil water (0–120 cm)
Rainfall	The growing season rainfall was 344 mm
PreDicta B	2.7 *Pratylenchus thornei*/g soil (medium risk), nil *P. neglectus* and nil crown rot was detected at sowing (0–15 cm)
Harvest date	7 December 2016

Treatments

Varieties (20)

- Four barley varieties: Commander⁽ᵈ⁾, Compass⁽ᵈ⁾, La Trobe⁽ᵈ⁾ and Spartacus⁽ᵈ⁾.
- Three durum varieties: Jandaroi⁽ᵈ⁾ and Lillaroi⁽ᵈ⁾ plus the numbered line 190873.
- Thirteen bread wheat varieties: EGA Gregory⁽ᵈ⁾, LRPB Flanker⁽ᵈ⁾, Beckom⁽ᵈ⁾, Coolah⁽ᵈ⁾, Sunmate⁽ᵈ⁾, LRPB Lancer⁽ᵈ⁾, LRPB Reliant⁽ᵈ⁾, LRPB Gauntlet⁽ᵈ⁾, LRPB Spitfire⁽ᵈ⁾, Mitch⁽ᵈ⁾, Suntop⁽ᵈ⁾ and Sunguard⁽ᵈ⁾; (listed in order of increasing resistance to crown rot) plus one numbered line LPB12-0494.

Pathogen treatment

Added or no added crown rot at sowing using sterilised durum grain colonised by at least five different isolates of *Fp* at a rate of 2.0 g/m of row at sowing.

Results

Yield

In the no added CR treatments, yield ranged from 3.76 t/ha in the barley variety Spartacus$^{\phi}$ up to 5.86 t/ha in the bread wheat variety Beckom$^{\phi}$ (Table 1).

All entries suffered significant yield loss under high levels of crown rot infection (added CR), which ranged from 7.6% in the bread wheat variety LRPB Spitfire$^{\phi}$ (0.44 t/ha) up to 29.1% in the barley variety Commander$^{\phi}$ (1.32 t/ha).

All four barley varieties were lower yielding than EGA Gregory$^{\phi}$ under high crown rot infection (added CR). The bread wheat entries (LPB12-0494, Sunguard$^{\phi}$ and LRPB Gauntlet$^{\phi}$) all produced a yield equivalent to EGA Gregory$^{\phi}$ in the added CR treatment (Table 1).

The bread wheat entries LRPB Spitfire$^{\phi}$ (1.33 t/ha), Beckom$^{\phi}$ (0.98 t/ha), Mitch$^{\phi}$ (0.81 t/ha), Coolah$^{\phi}$ (0.71 t/ha), Sunmate$^{\phi}$ (0.61 t/ha), LRPB Flanker$^{\phi}$ (0.48 t/ha), LRPB Lancer$^{\phi}$ (0.39 t/ha), LRPB Reliant$^{\phi}$ (0.33 t/ha) and LPB12-0494 (0.30 t/ha) were all higher yielding than EGA Gregory$^{\phi}$ under high levels of crown rot infection (added CR; Table 1).

Table 1. Yield and grain quality of varieties with no added and added crown rot – Bullarah 2016.

Crop	Variety	Yield (t/ha)		Protein	Screenings
		No added CR	Added CR	(%)	(%)
Barley	Compass	4.53	3.72	14.5	2.2
	La Trobe	4.01	3.48	14.8	6.2
	Commander	4.54	3.22	14.2	4.1
	Spartacus	3.76	3.17	15.3	6.2
Durum	DBA Lillaroi	5.29	4.76	15.8	4.8
	190873	5.31	4.58	14.9	4.1
	Jandaroi	5.59	4.52	14.6	4.6
Bread wheat	LRPB Spitfire	5.84	5.39	14.4	8.4
	Beckom	5.86	5.04	12.7	5.2
	Mitch	5.45	4.87	12.0	6.5
	Coolah	5.32	4.77	12.3	5.4
	Sunmate	5.28	4.67	12.7	7.0
	LRPB Flanker	5.03	4.54	12.9	6.0
	LRPB Lancer	5.60	4.45	13.6	6.9
	Suntop	5.04	4.39	12.8	5.8
	LRPB Reliant	4.74	4.36	12.5	8.6
	LPB12-0494	4.84	4.33	12.5	9.5
	Sunguard	4.93	4.32	12.7	7.3
	EGA Gregory	4.67	4.06	12.5	7.8
	LRPB Gauntlet	4.28	3.90	12.9	8.3
Site mean		5.00	4.33	13.5	6.2
CV (%)		3.9		1.2	19.2
l.s.d.		0.296		0.19	1.38
P value		<.001		<.001	<.001

Grain quality

Protein levels were relatively high at this site in 2016 and ranged from 12.0% (Mitch⊕) up to 15.8% (DBA Lillaroi⊕; Table 1). The recently released durum variety DBA Lillaroi⊕ achieved 0.9–1.2% higher grain protein levels than the other two durum entries in the experiment. Crown rot infection (added CR) did not significantly affect grain protein levels in any of the entries at this site in 2016.

Screening levels ranged from 2.2% in the barley variety Compass⊕ up to 9.5% in the bread wheat line LPB12-0494 (Table 1). Crown rot infection (added CR) did not significantly affect grain protein levels in any of the entries at this site in 2016. The three durum varieties produced similar screenings levels to each other, in the range of 4.2–4.8%.

Conclusions

Cereal crop and variety choice provided a 7–33% yield benefit over growing the susceptible bread wheat variety EGA Gregory⊕ under high levels of crown rot infection at Bullarah in 2016. This could have maximised profit in the growing season but will **not** reduce inoculum levels for subsequent crops, because all winter cereal varieties are susceptible to crown rot infection. Winter cereal crop and variety choice is therefore **not** the sole solution to crown rot but rather just one element of an integrated management strategy to limit losses from this disease.

Acknowledgements

This research was part of the project *National crown rot epidemiology and management program* (DAN00175), with joint investment by NSW DPI and GRDC. Thanks to Brad Coleman for providing the experiment site and Rick Graham, Jim Perfrement, Mick Dal Santo, Stephen Morphett (NSW DPI) for sowing, maintaining and harvesting the trial. Thanks to Chrystal Fensbo (NSW DPI) for grain quality assessments and to Jason Lowien (GrainCorp) for use of an NIR machine to determine grain protein levels.

Regional crown rot management – Gilgandra 2016

Steven Simpfendorfer[1], Greg Brooke[2], Ryan Potts[3] and Robyn Shapland[1]
[1]NSW DPI Tamworth
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Key findings

- Yield loss from crown rot ranged from not significant in the variety DBA Lillaroi$^{\phi}$ and seven of the 13 bread wheat varieties, up to 32.9% in the durum variety Jandaroi$^{\phi}$.
- Only the bread wheat variety Mitch$^{\phi}$ was higher yielding (0.41 t/ha) than the susceptible bread wheat variety EGA Gregory$^{\phi}$ in the presence of high levels of crown rot infection.
- Grain protein levels were low across the site and varied from 7.7% in Mitch$^{\phi}$ up to 10.1% in the durum line 190873. Crown rot infection did not affect protein levels in any entry.
- Crown rot infection caused a small (1–2%), but significant, increase in the level of screenings in the barley variety La Trobe$^{\phi}$, and 10 of the 13 bread wheat entries.

Introduction

Crown rot (CR), caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to winter cereal production in the northern grains region. Cereal varieties differ in their resistance to crown rot, which can have a significant effect on their relative yield in the presence of this disease.

This experiment was one of 11 conducted by NSW DPI in 2016 across central/northern NSW extending into southern Qld, to examine the impact of crown rot on the yield and quality of four barley, three durum and 13 bread wheat varieties.

Site details

Location	'Avondale', Gilgandra
Co-operator	Kevin Kilby
Sowing date	25 May 2016
Fertiliser	80 kg/ha Granulock 12Z (treated with 2.8 L/ha of flutriafol) at sowing
Starting nitrogen	97 kg N/ha to 120 cm
Starting soil water	~120 mm plant available soil water (0–120 cm)
Rainfall	The growing season rainfall was 574 mm
PreDicta B	Nil *Pratylenchus thornei*, nil *P. neglectus* and nil crown rot at sowing (0–15 cm)
Harvest date	30 November 2016

Treatments

Varieties (20)

- Four barley varieties: Commander$^{\phi}$, Compass$^{\phi}$, La Trobe$^{\phi}$ and Spartacus$^{\phi}$.
- Three durum varieties: Jandaroi$^{\phi}$ and Lillaroi$^{\phi}$ plus the numbered line 190873.
- Thirteen bread wheat varieties: EGA Gregory$^{\phi}$, LRPB Flanker$^{\phi}$, Beckom$^{\phi}$, Coolah$^{\phi}$, Sunmate$^{\phi}$, LRPB Lancer$^{\phi}$, LRPB Reliant$^{\phi}$, LRPB Gauntlet$^{\phi}$, LRPB Spitfire$^{\phi}$, Mitch$^{\phi}$, Suntop$^{\phi}$ and Sunguard$^{\phi}$; (listed in order of increasing resistance to crown rot) plus one numbered line LPB12-0494.

Pathogen treatment

Added or no added crown rot at sowing using sterilised durum grain colonised by at least five different isolates of *Fp* at a rate of 2.0 g/m of row at sowing.

Results

Yield

In the no added CR treatment, yield ranged from 2.16 t/ha in the barley variety La Trobe$^{\phi}$ up to 3.55 t/ha in the bread wheat variety Beckom$^{\phi}$ (Table 1). Waterlogging at early growth stages (up to GS32) was evident at this site in 2016, which appeared more pronounced in the barley varieties than in the bread or durum wheat entries.

The durum variety DBA Lillaroi$^{\phi}$ and seven of the bread wheat varieties (Mitch$^{\phi}$, LRPB Flanker$^{\phi}$, LRPB Spitfire$^{\phi}$, Suntop$^{\phi}$, LRPB Reliant$^{\phi}$, LRPB Gauntlet$^{\phi}$ and Sunguard$^{\phi}$) did not suffer significant yield loss under high levels of crown rot infection (added CR). In the remaining entries, yield loss ranged from 9.6% in the bread wheat variety Coolah$^{\phi}$ (0.32 t/ha) up to 32.9% in the durum variety Jandaroi$^{\phi}$ (0.84 t/ha).

All four barley varieties and all three durum entries were lower yielding than EGA Gregory$^{\phi}$ under high crown rot infection (added CR). With the exception of Mitch$^{\phi}$, all the bread wheat entries produced a yield equivalent to EGA Gregory$^{\phi}$ in the added CR treatment (Table 1).

The bread wheat variety Mitch$^{\phi}$ (0.41 t/ha) was the only entry that was higher yielding than EGA Gregory$^{\phi}$ under high levels of crown rot infection (added CR; Table 1).

Table 1. Yield and grain quality of varieties with no added and added crown rot – Gilgandra 2016.

Crop	Variety	Yield (t/ha)		Protein	Screenings (%)	
		No added CR	Added CR	(%)	No added CR	Added CR
Barley	Commander	2.22	1.87	8.2	2.1	2.4
	Spartacus	2.58	1.86	8.8	2.1	2.7
	Compass	2.37	1.77	8.4	1.7	2.1
	La Trobe	2.16	1.48	9.3	2.7	4.0
Durum	DBA Lillaroi	2.23	2.03	9.5	2.0	2.6
	190873	2.49	1.86	10.1	1.8	2.4
	Jandaroi	2.57	1.72	9.8	2.4	2.8
Bread wheat	Mitch	3.52	3.26	7.7	5.0	6.4
	Beckom	3.55	3.08	7.8	4.0	5.0
	Coolah	3.34	3.02	8.9	5.5	6.8
	LRPB Flanker	3.19	2.97	8.3	5.7	7.4
	LRPB Spitfire	3.05	2.91	9.2	4.9	5.6
	Sunmate	3.26	2.89	8.9	8.0	10.3
	Suntop	3.11	2.87	8.6	6.0	6.0
	EGA Gregory	3.23	2.85	8.6	6.4	8.1
	LRPB Reliant	3.05	2.82	8.4	6.9	7.8
	LRPB Gauntlet	2.89	2.78	8.9	5.9	7.0
	LPB12-0494	3.14	2.75	8.8	7.6	8.7
	Sunguard	2.76	2.71	8.7	4.6	4.7
	LRPB Lancer	2.97	2.55	9.2	3.6	4.7
Site mean		2.88	2.50	8.8	4.4	5.4
CV (%)		7.1		4.5	11.0	
l.s.d.		0.310		0.46	0.87	
P value		0.021		<.001	0.05	

Grain quality

Protein levels were low at this site in 2016 and ranged between 7.7% (Mitch$^{\phi}$) up to 10.1% (190873; Table 1). The low protein levels were likely related to denitrification that occurred with transient water logging at the site early in the season.

Crown rot infection (added CR) did not significantly affect grain protein levels in any of the entries at this site in 2016.

In the no added CR treatment, screening levels ranged from 1.7% in the barley variety Compass$^{(|)}$ up to 8.0% in the bread wheat variety Sunmate$^{(|)}$ (Table 1).

Screening levels were increased by around 1–2% in the added CR treatment with the barley variety La Trobe$^{(|)}$ and the bread wheat entries Mitch$^{(|)}$, Beckom$^{(|)}$, Coolah$^{(|)}$, LRPB Flanker$^{(|)}$, Sunmate$^{(|)}$, EGA Gregory$^{(|)}$, LRPB Reliant$^{(|)}$, LRPB Gauntlet$^{(|)}$, LPB12-0494 and LRPB Lancer$^{(|)}$. In the remaining entries, there was no significant difference in the level of screenings between the no added CR and added CR treatments. In the added CR treatment, screening levels ranged from 2.1% in the barley variety Compass$^{(|)}$ up to 10.3% in the bread wheat variety Sunmate$^{(|)}$ (Table 1).

Conclusions

Cereal crop and variety choice affected yield in the absence and presence of crown rot infection, which differed by 1.38 t/ha and 1.77 t/ha, respectively between the best and worst entries. Waterlogging at this site during tillering visually affected the barley varieties more than the bread and durum wheat entries. This difference appears to have carried through to a reduced yield in the barley varieties relative to the other winter cereals at this site in 2016.

Only the bread wheat variety Mitch$^{(|)}$ provided a 14% yield benefit over growing the susceptible bread wheat variety EGA Gregory$^{(|)}$ under high levels of crown rot infection at Gilgandra in 2016. This could have maximised profit in this growing season but will **not** reduce inoculum levels for subsequent crops, because all winter cereal varieties are susceptible to crown rot infection. Winter cereal crop and variety choice is therefore **not** the sole solution to crown rot but rather just one element of an integrated management strategy to limit losses from this disease.

Acknowledgements

This research was part of the project *National crown rot epidemiology and management program* (DAN00175), with joint investment by NSW DPI and GRDC. Thanks to Kevin Kilby for providing the experimental site and Peter Matthews (NSW DPI) for assistance with organising operations at the experimental site. Thanks to Chrystal Fensbo (NSW DPI) for grain quality assessments and to Jason Lowien (GrainCorp) for use of an NIR machine to determine grain protein levels.

Regional crown rot management – Wongarbon 2016

Steven Simpfendorfer[1], Greg Brooke[2], Ryan Potts[3] and Robyn Shapland[1]
[1]NSW DPI, Tamworth
[2]NSW DPI, Trangie
[3]NSW DPI, Dubbo

Key findings

- Seasonal conditions reduced stress during grain fill at this site in 2016, which limited the effects from infection on yield.
- Although the effect of crown rot infection on yield was not significant, there was still a 52% (1.76 t/ha) difference between the overall yield of the best and worst entries.
- Grain protein levels were relatively low across the site, varying from 7.8% in Mitch⍉ up to 9.8% in the durum line 190873. Crown rot did not affect protein levels in any other variety.
- Crown rot infection caused a moderate (2–6%) increase in the level of screenings in 10 of the 13 bread wheat entries.

Introduction

Crown rot (CR), caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to winter cereal production in the northern grains region. Cereal varieties differ in their resistance to crown rot, which can significantly affect their relative yield in the presence of this disease.

This experiment was one of 11 conducted by NSW DPI in 2016 across central/northern NSW extending into southern Qld; to examine the effects of crown rot on the yield and quality of four barley, three durum and 13 bread wheat varieties.

Site details

Location	'Hillview', Wongarbon
Co-operator	The Kelly family
Sowing date	31 May 2016
Fertiliser	80 kg/ha Granulock 12 Z (treated with 2.8 L/ha of flutriafol) at sowing 100 L/ha Easy N at Z30
Starting nitrogen	145 kg N/ha to 120 cm
Starting soil water	~120 mm plant available soil water (0–120 cm)
Rainfall	The growing season rainfall was 555 mm
PreDicta B	Nil *Pratylenchus thornei*, 1.8 *P. neglectus*/g soil (low risk) and nil crown rot at sowing (0–15 cm)
Harvest date	2 December 2016

Treatments

Varieties (20)

- Four barley varieties: Commander⍉, Compass⍉, La Trobe⍉ and Spartacus⍉.
- Three durum varieties: Jandaroi⍉ and Lillaroi⍉ plus the numbered line 190873.
- Thirteen bread wheat varieties: EGA Gregory⍉, LRPB Flanker⍉, Beckom⍉, Coolah⍉, Sunmate⍉, LRPB Lancer⍉, LRPB Reliant⍉, LRPB Gauntlet⍉, LRPB Spitfire⍉, Mitch⍉, Suntop⍉ and Sunguard⍉; (listed in order of increasing resistance to crown rot) plus one numbered line LPB12-0494.

Pathogen treatment

Added or no added crown rot at sowing using sterilised durum grain colonised by at least five different isolates of *Fp* at a rate of 2.0 g/m of row at sowing.

Results

Yield

Adding CR inoculum at sowing did not significantly affect the yield of individual varieties at this site in 2016. However, significant differences were still evident between varieties averaged across CR treatments. Yield in the four barley varieties ranged from 4.92 t/ha in Compass$^{\phi}$ up to 5.15 t/ha in Spartacus$^{\phi}$. Durum yield ranged from 3.38 t/ha in DBA Lillaroi$^{\phi}$ up to 3.68 t/ha with Jandaroi$^{\phi}$, while bread wheat yield ranged from 3.99 t/ha with LRPB Lancer$^{\phi}$ up to 4.92 t/ha with Mitch$^{\phi}$ (Table 1).

Grain quality

Protein levels were low at this site in 2016 and ranged between 7.8% (Mitch$^{\phi}$ and Beckom$^{\phi}$) up to 9.8% (190873; Table 1). Crown rot infection (added CR) did not significantly affect grain protein levels in any of the entries at this site in 2016.

The added CR treatment increased screening levels by between 1.9 to 5.6% in the bread wheat varieties Beckom$^{\phi}$, Coolah$^{\phi}$, LRPB Flanker$^{\phi}$, Mitch$^{\phi}$, EGA Gregory$^{\phi}$, LRPB Gauntlet$^{\phi}$, LRPB Lancer$^{\phi}$, Sunguard$^{\phi}$, LRPB Reliant$^{\phi}$ and Sunmate$^{\phi}$. In the remaining bread wheat entries, there was no significant difference in the level of screenings between the no added CR and added CR treatments.

Table 1. Yield and grain quality of varieties with no added and added crown rot – Wongarbon 2016.

Crop	Variety	Yield	Protein	Screenings (%)	
		(t/ha)	(%)	No added CR	Added CR
Barley	Spartacus	5.15	9.0	1.8	2.3
	Commander	5.06	7.9	1.7	1.8
	La Trobe	4.93	8.5	2.4	3.0
	Compass	4.92	8.3	1.4	1.6
Durum	Jandaroi	3.68	9.7	3.2	4.0
	190873	3.48	9.8	2.5	3.1
	DBA Lillaroi	3.38	9.6	3.5	4.1
Bread wheat	Mitch	4.92	7.8	4.3	6.7
	LRPB Flanker	4.83	8.5	6.4	8.8
	Beckom	4.78	7.8	4.6	6.4
	LRPB Reliant	4.74	8.2	8.6	12.5
	LPB12-0494	4.73	9.1	6.8	8.1
	EGA Gregory	4.53	8.7	9.1	12.4
	Coolah	4.42	9.1	5.9	7.9
	Sunmate	4.35	8.8	11.9	17.5
	LRPB Gauntlet	4.34	8.8	7.7	11.3
	Suntop	4.30	8.7	6.2	7.4
	Sunguard	4.28	8.8	5.8	9.6
	LRPB Spitfire	4.23	9.1	5.4	6.9
	LRPB Lancer	3.99	9.1	5.8	9.6
Site mean		4.45	8.8	5.2	7.3
CV (%)		4.3	4.3	17.7	
l.s.d.		0.219	0.44	1.80	
P value		<.001	<.001	<.001	

Conclusions

Cereal crop and variety choice affected yield at this site in 2016, which differed by 1.76 t/ha (52%) between the best (Spartacus(D)) and worst (DBA Lillaroi(D)) entries when averaged across CR treatments. CR treatment did not significantly affect yield in any of the entries due to seasonal conditions (~120 mm of plant available water at sowing plus 555 mm in-crop rainfall), which limited stress during grain filling. The added CR treatment also did not affect grain protein levels, but resulted in a modest 2–6% increase in the level of screenings in 10 of the 13 bread wheat entries.

It should be remembered that cereal crop and variety choice in paddocks with a medium crown rot risk can maximise profit in the current season, but will **not** reduce inoculum levels for subsequent crops because all winter cereal varieties are susceptible to crown rot infection. Winter cereal crop and variety choice is therefore **not** the sole solution to crown rot, but rather just one element of an integrated management strategy to limit losses from this disease.

Acknowledgements

This research was part of the project *National crown rot epidemiology and management program* (DAN00175), with joint investment by NSW DPI and GRDC. Thanks to the Kelly family for providing the experiment site and Peter Matthews (NSW DPI) for assistance in organising operations at the site. Thanks to Chrystal Fensbo (NSW DPI) for grain quality assessments and to Jason Lowien (GrainCorp) for use of an NIR machine to determine grain protein levels.

Regional crown rot management – Parkes 2016

Steven Simpfendorfer[1], Ryan Potts[2] and Robyn Shapland[1]
[1]NSW DPI Tamworth
[2]NSW DPI Dubbo

Key findings

- Yield loss from crown rot ranged from not significant in the bread wheat varieties Mitch⊕ and Beckom⊕ up to 18.6% in the bread wheat variety LRPB Flanker⊕.
- The two barley varieties Spartacus ⊕ and La Trobe⊕ along with nine of the bread wheat entries were higher yielding (0.28 t/ha to 0.86 t/ha) in the presence of high levels of crown rot infection than EGA Gregory⊕.
- Grain protein levels were relatively low at across the site which varied from 9.2% in Coolah⊕ up to 11.5% in the barley variety Spartacus⊕ . Protein levels in all other entries were not affected by crown rot infection.
- Crown rot infection caused a small (0.6 to 1.4%) but significant increase in the level of screenings in the four barley varieties and four of the thirteen bread wheat entries but remained below 5% for all entries.

Introduction

Crown rot (CR) caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to the production of winter cereals in the northern grains region. 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.

This experiment was one of 11 conducted by NSW DPI in 2016 across central/northern NSW extending into southern Qld; to examine the impact of crown rot on the yield and quality of four barley, three durum and 13 bread wheat varieties.

Site details

Location	'Kundibah', North Parkes Mine
Co-operator	Matthew Burkitt
Sowing date	21 May 2016
Fertiliser	80 kg/ha Granulock 12Z (treated with 2.8 L/ha of flutriafol) and 80 kg N/ha as Urea applied at sowing
Starting soil water	~100 mm plant available soil water (0–120 cm)
Rainfall	The growing season rainfall was 475 mm
PreDicta B	Nil *Pratylenchus thornei*, 0.4 *P. neglectus*/g soil (low risk) and 0.8 log *Fusarium*/g soil (low crown rot risk) at sowing (0–15 cm)
Harvest date	2 December 2016

Treatments

Varieties (20)

- Four barley varieties: Commander⊕, Compass⊕, La Trobe⊕ and Spartacus⊕.
- Three durum varieties: Jandaroi⊕ and DBA Lillaroi⊕ plus the numbered line 190873.
- Thirteen bread wheat varieties: EGA Gregory⊕, LRPB Flanker⊕, Beckom⊕, Coolah⊕, Sunmate⊕, LRPB Lancer⊕, LRPB Reliant⊕, LRPB Gauntlet⊕, LRPB Spitfire⊕, Mitch⊕, Suntop⊕ and Sunguard⊕; (listed in order of increasing resistance to crown rot) plus one numbered line LPB12-0494.

Pathogen treatment

Added or no added crown rot at sowing using sterilised durum grain colonised by at least five different isolates of *Fp* at a rate of 2.0 g/m of row at sowing.

Results

Yield

In the no added CR treatment, yields ranged from 4.82 t/ha in the durum line 190873 up to 5.51 t/ha in the bread wheat variety Coolah⟃ (Table 1). The bread wheat varieties Mitch⟃ and Beckom⟃ did not suffer significant yield loss under high levels of crown rot infection (added CR). In the remaining entries, yield loss ranged from 5.7% in the bread wheat variety Coolah⟃ (0.31 t/ha) up to 18.6% in the bread wheat variety LRPB Flanker⟃ (1.02 t/ha).

No entry was lower yielding than EGA Gregory⟃ under high crown rot infection (added CR). The barley varieties Commander⟃ and Compass⟃, the three durum entries and bread wheat varieties LRPB Gauntlet⟃, LRPB Spitfire⟃ and LRPB Flanker⟃ all produced yields equivalent to EGA Gregory⟃ in the added CR treatment (Table 1).

The barley varieties Spartacus⟃ (0.69 t/ha) and La Trobe⟃ (0.59 t/ha), along with the bread wheat entries Coolah⟃ (0.86 t/ha), Mitch⟃ (0.84 t/ha), Suntop⟃ (0.75 t/ha), LRPB Lancer⟃ (0.72 t/ha), Beckom⟃ (0.71 t/ha), Sunmate⟃ (0.50 t/ha), LRPB Reliant⟃ (0.36 t/ha), Sunguard⟃ (0.35 t/ha) and LPB12-0494 (0.28 t/ha) were higher yielding than EGA Gregory⟃ under high levels of crown rot infection (added CR; Table 1).

Table 1. Yield and grain quality of varieties with no added and added crown rot – Parkes 2016.

Crop	Variety	Yield (t/ha)		Protein	Screenings (%)	
		No added CR	Added CR	(%)	No added CR	Added CR
Barley	Spartacus	5.38	5.03	11.5	1.6	3.0
	La Trobe	5.45	4.93	11.4	1.6	2.3
	Commander	4.87	4.55	10.1	2.0	2.9
	Compass	4.96	4.18	10.8	1.0	2.2
Durum	DBA Lillaroi	4.95	4.47	10.6	1.4	1.7
	Jandaroi	5.01	4.46	10.9	1.3	1.6
	190873	4.82	4.31	11.2	1.1	1.5
Bread wheat	Coolah	5.51	5.20	9.2	2.0	2.4
	Mitch	5.41	5.18	9.4	2.5	2.1
	Suntop	5.46	5.09	10.4	2.2	2.7
	LRPB Lancer	5.38	5.06	10.0	2.3	2.7
	Beckom	5.20	5.05	9.5	2.6	2.8
	Sunmate	5.41	4.84	9.8	3.4	4.7
	LRPB Reliant	5.13	4.70	9.9	3.1	3.9
	Sunguard	5.21	4.69	10.4	2.4	3.1
	LPB12-0494	5.06	4.62	9.8	4.0	4.8
	LRPB Gauntlet	4.97	4.58	10.6	2.4	2.9
	LRPB Spitfire	5.07	4.56	11.2	1.9	2.1
	LRPB Flanker	5.49	4.47	9.6	2.1	2.6
	EGA Gregory	5.19	4.34	9.8	2.3	2.7
Site mean		5.20	4.72	10.3	2.2	2.7
CV (%)		3.4		4.4	15.5	
l.s.d		0.271		0.52	0.62	
P value		0.004		<.001	0.047	

Crop protection

Grain quality

Only moderate protein levels were achieved at this site in 2016, which ranged from 9.2% (Coolah$^{\phi}$) up to 11.5% (Spartacus$^{\phi}$; Table 1). Crown rot infection (added CR) did not significantly affect grain protein levels in any of the entries at this site in 2016.

In the no added CR treatment, screening levels ranged from 1.0% in the barley variety Compass$^{\phi}$ up to 4.0% in the bread wheat line LPB12-0494 (Table 1). Screening levels increased by 0.6–1.4% in the added CR treatment with the four barley varieties and the bread wheat entries Sunmate$^{\phi}$, LRPB Reliant$^{\phi}$, Sunguard$^{\phi}$ and LPB12-0494. In the remaining entries, there was no significant difference in the level of screenings between the no added CR and added CR treatments. In the added CR treatment, screening levels ranged from 1.5% in the durum line 190873 up to 4.8% in the bread wheat line LPB12-0494 (Table 1).

Conclusions

Cereal crop and variety choice provided a 6–20% yield benefit over growing the susceptible bread wheat variety EGA Gregory$^{\phi}$ under high levels of crown rot infection at Parkes in 2016. This could have maximised profit in this growing season but will **not** reduce inoculum levels for subsequent crops because all winter cereal varieties are susceptible to crown rot infection. Winter cereal crop and variety choice is therefore **not** the sole solution to crown rot, but rather just one element of an integrated management strategy to limit losses from this disease.

Acknowledgements

This research was part of the project *National crown rot epidemiology and management program* (DAN00175), with joint investment by NSW DPI and GRDC. Thanks to Matthew Burkitt and the North Parkes Mine for providing the experiment site and Peter Matthews and Pete Roberts (NSW DPI) for assistance in sowing, maintaining and harvesting the experiment. Thanks to Chrystal Fensbo (NSW DPI) for grain quality assessments and to Jason Lowien (GrainCorp) for use of an NIR machine to determine grain protein levels.

Regional crown rot management – Edgeroi 2016

Steven Simpfendorfer and Robyn Shapland
NSW DPI, Tamworth

Key findings

- Yield loss from crown rot ranged from not significant in four of the bread wheat varieties up to 14.9% in the barley variety CompassΦ.
- Bread wheat variety choice affected yield in the presence of high levels of crown rot infection with eight entries being between 0.29 t/ha and 0.76 t/ha higher yielding than EGA GregoryΦ.
- Grain protein levels varied from 11.9% in BeckomΦ up to 14.7% in the recently released durum variety DBA LillaroiΦ. Crown rot did not affect protein levels in any other entry.
- Screening levels varied from 4.4% in the barley variety CompassΦ and bread wheat variety CoolahΦ up to 9.3% in the barley variety SpartacusΦ. Crown rot did not affect screenings in any other entry.

Introduction

Crown rot (CR) caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to winter cereal production in the northern grains region. Cereal varieties differ in their resistance to crown rot, which can have a significant affect on their relative yield in the presence of this disease.

This experiment was one of 11 conducted by NSW DPI in 2016 across central/northern NSW extending into southern Qld; to examine the effects from crown rot on the yield and quality of four barley, three durum and 13 bread wheat varieties.

Site details

Location	'Coolatoota', Edgeroi
Co-operator	Andrew Campbell
Sowing date	19 May 2016
Fertiliser	136 kg/ha urea and 60 kg/ha Granulock 12Z (treated with 400 mL/ha of flutriafol) at sowing
Starting nitrogen	165 kg N/ha to 120 cm
Starting soil water	99 mm plant available soil water (0–120 cm)
Rainfall	The growing season rainfall was 323 mm
PreDicta B	Nil *Pratylenchus thornei*, nil *P. neglectus* and 0.7 log *Fusarium* DNA/g soil (low crown rot risk) at sowing (0–15 cm)
Harvest date	4 December 2016

Treatments

Varieties (20)

- Four barley varieties: CommanderΦ, CompassΦ, La TrobeΦ and SpartacusΦ.
- Three durum varieties: JandaroiΦ and DBA LillaroiΦ plus the numbered line 190873.
- Thirteen bread wheat varieties: EGA GregoryΦ, LRPB FlankerΦ, BeckomΦ, CoolahΦ, SunmateΦ, LRPB LancerΦ, LRPB ReliantΦ, LRPB GauntletΦ, LRPB SpitfireΦ, MitchΦ, SuntopΦ and SunguardΦ; (listed in order of increasing resistance to crown rot) plus one numbered line LPB12-0494.

Pathogen treatment

Added or no added crown rot at sowing using sterilised durum grain colonised by at least five different isolates of *Fp* at a rate of 2.0 g/m of row at sowing.

Results

Yield

In the no added CR treatment, yield ranged from 3.85 t/ha in the barley variety Commander[Φ] up to 5.92 t/ha in the bread wheat variety Beckom[Φ] (Table 1).

The bread wheat varieties Beckom[Φ], Suntop[Φ], LRPB Gauntlet[Φ] and LRPB Reliant[Φ] did not suffer significant yield loss under high levels of crown rot infection (added CR). The remaining entries suffered significant yield loss under high levels of crown rot infection (added CR), ranging from 4.2% in the bread wheat variety Sunmate[Φ] (0.25 t/ha) up to 14.9% in the barley variety Compass[Φ] (0.68 t/ha).

All four barley varieties and all three durum entries were lower yielding than EGA Gregory[Φ] under high crown rot infection (added CR). The bread wheat varieties LRPB Spitfire[Φ], Sunguard[Φ], LRPB Flanker[Φ] and LRPB Reliant[Φ] all produced yields equivalent to EGA Gregory[Φ] in the added CR treatment (Table 1).

The bread wheat entries Beckom[Φ] (0.76 t/ha), Sunmate[Φ] (0.60 t/ha), Suntop[Φ] (0.56 t/ha), Mitch[Φ] (0.52 t/ha), Coolah[Φ] (0.52[Φ] t/ha), LRPB Lancer[Φ] (0.41 t/ha), LRPB Gauntlet[Φ] (0.34 t/ha) and LPB12-0494 (0.29 t/ha) were all higher yielding than EGA Gregory[Φ] under high levels of crown rot infection (added CR; Table 1).

Table 1. Yield and grain quality of varieties with no added and added crown rot – Edgeroi 2016.

Crop	Variety	Yield (t/ha)		Protein	Screenings
		No added CR	Added CR	(%)	(%)
Barley	Spartacus	4.85	4.46	14.4	9.3
	La Trobe	4.84	4.16	13.7	7.9
	Compass	4.58	3.89	12.7	4.4
	Commander	3.85	3.44	13.7	8.1
Durum	DBA Lillaroi	4.92	4.57	14.7	7.3
	Jandaroi	4.77	4.38	14.0	5.6
	190873	4.68	4.11	14.5	7.2
Bread wheat	Beckom	5.92	5.79	11.9	5.1
	Sunmate	5.88	5.63	12.3	8.9
	Suntop	5.81	5.59	12.3	5.1
	Mitch	5.83	5.55	12.0	5.0
	Coolah	5.83	5.55	12.3	4.4
	LRPB Lancer	5.71	5.44	13.2	5.1
	LRPB Gauntlet	5.55	5.37	12.5	6.2
	LPB12-0494	5.72	5.32	12.4	8.5
	LRPB Spitfire	5.67	5.12	14.5	5.1
	Sunguard	5.46	5.12	12.4	7.4
	LRPB Flanker	5.64	5.08	12.7	6.1
	EGA Gregory	5.50	5.03	12.8	6.3
	LRPB Reliant	5.01	4.86	12.6	6.7
Site mean		5.30	4.92	13.1	6.5
CV (%)		2.8		2.2	25.6
l.s.d.		0.236		0.33	1.91
P value		0.021		<.001	<.001

Grain quality

Protein levels were relatively high at this site in 2016, ranging from 11.9% (Beckom[Φ]) up to 14.7% (DBA Lillaroi[Φ]; Table 1). Crown rot infection (added CR) did not significantly affect grain protein levels in any of the entries at this site in 2016.

Screening levels ranged from 4.4% in the barley variety Compass[⊕] and bread wheat variety Coolah[⊕] up to 9.3% in the barley variety Spartacus[⊕] (Table 1). Crown rot infection (added CR) did not significantly affect grain protein levels in any of the entries at this site in 2016.

Conclusions

Bread wheat variety choice provided a 6–15% yield benefit over growing the susceptible bread wheat variety EGA Gregory[⊕] under high levels of crown rot infection at Edgeroi in 2016. This could have maximised profit in this growing season, but will **not** reduce inoculum levels for subsequent crops because all winter cereal varieties are susceptible to crown rot infection. Winter cereal crop and variety choice is therefore **not** the sole solution to crown rot, but rather just one element of an integrated management strategy to limit losses from this disease.

Acknowledgements

This research was part of the project *National crown rot epidemiology and management program* (DAN00175), with joint investment by NSW DPI and GRDC. Thanks to Andrew Campbell for providing the experiment site and Rick Graham, Jim Perfrement, Mick Dal Santo, Stephen Morphett (NSW DPI) for sowing, maintaining and harvesting the experiment. Thanks to Chrystal Fensbo (NSW DPI) for grain quality assessments and to Jason Lowien (GrainCorp) for use of an NIR machine to determine grain protein levels.

Regional crown rot management – Merriwa 2016

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Key findings

- Yield loss from crown rot ranged from not significant in the barley variety Compass⊕, durum entries 190873 and Jandaroi⊕ and six of the bread wheat varieties, up to 19.7% in the barley variety Commander⊕.
- Only the bread wheat variety Beckom⊕ was higher yielding (by 0.58 t/ha) in the presence of high levels of crown rot infection than the susceptible bread wheat variety EGA Gregory⊕.
- Grain protein levels were very low across the site (average 8.2%) and varied from 7.5% in LRPB Reliant⊕ up to 8.9% in LRPB Spitfire⊕. Crown rot did not affect protein levels in any entry.
- Screening levels were very low across entries, but crown rot infection caused a small (0.5–1.3%), yet significant, increase in the level of screenings in the barley varieties Compass⊕ and Commander⊕, as well as in the bread wheat varieties Coolah⊕ and LRPB Spitfire⊕.

Introduction

Crown rot (CR), caused predominantly by the fungus *Fusarium pseudograminearum* (*Fp*), remains a major constraint to winter cereal production in the northern grains region. Cereal varieties differ in their resistance to crown rot, which can have a significant effect on their relative yield when the disease is present.

This experiment was one of 11 conducted by NSW DPI in 2016 across central/northern NSW extending into southern Qld; to examine how crown rot affects the yield and quality of four barley, three durum and 13 bread wheat varieties.

Site details

Location	'Woodlands", Merriwa
Co-operator	Mark Campbell
Sowing date	2 June 2016
Fertiliser	90 kg/ha Granulock 12Z at sowing
Rainfall	The growing season rainfall was 378 mm
PreDicta B	0.5 *Pratylenchus thornei*/g soil (low risk), 0.4 *P. neglectus*/g soil (low risk) and 1.5 log *Fusarium* DNA/g soil (medium crown rot risk) at sowing (0–15 cm)
Harvest date	8 December 2016

Treatments

Varieties (20)

- Four barley varieties: Commander⊕, Compass⊕, La Trobe⊕ and Spartacus⊕.
- Three durum varieties: Jandaroi⊕ and Lillaroi⊕ plus the numbered line 190873.
- Thirteen bread wheat varieties: EGA Gregory⊕, LRPB Flanker⊕, Beckom⊕, Coolah⊕, Sunmate⊕, LRPB Lancer⊕, LRPB Reliant⊕, LRPB Gauntlet⊕, LRPB Spitfire⊕, Mitch⊕, Suntop⊕ and Sunguard⊕; (listed in order of increasing resistance to crown rot) plus one numbered line LPB12-0494.

Pathogen treatment

Added or no added crown rot at sowing using sterilised durum grain colonised by at least five different isolates of *Fp* at a rate of 2.0 g/m of row at sowing.

Results

Yield

In the no added CR treatment, yield ranged from 3.55 t/ha in the durum variety Jandaroi$^{\phi}$ up to 4.96 t/ha in the barley variety Commander$^{\phi}$ (Table 1). The barley variety Compass$^{\phi}$, durum entries 190873 and Jandaroi$^{\phi}$, along with six of the bread wheat varieties (Beckom$^{\phi}$, Coolah$^{\phi}$, LRPB Spitfire$^{\phi}$, LRPB Lancer$^{\phi}$, LRPB Gauntlet$^{\phi}$ and Suntop$^{\phi}$) did not suffer significant yield loss under high levels of crown rot infection (added CR). In the remaining entries yield loss ranged from 9.4% in the bread wheat variety LRPB Reliant$^{\phi}$ (0.42 t/ha) up to 19.7% in the barley variety Commander$^{\phi}$ (0.98 t/ha).

All three durum entries and the bread wheat varieties Sunguard$^{\phi}$ and Sunmate$^{\phi}$ were lower yielding than EGA Gregory$^{\phi}$ under high crown rot infection (added CR). With the exception of Beckom$^{\phi}$, the remaining bread wheat entries, along with the four barley varieties, produced yield equivalent to EGA Gregory$^{\phi}$ in the added CR treatment (Table 1).

The bread wheat variety Beckom$^{\phi}$ (0.58 t/ha) was the only entry that was higher yielding than EGA Gregory$^{\phi}$ under high levels of crown rot infection (added CR; Table 1).

Grain quality

Protein levels were low at this site in 2016 and ranged between 7.5% (LRPB Reliant$^{\phi}$) up to 8.9% (LRPB Spitfire$^{\phi}$; Table 1). The low protein levels were likely related to denitrification that occurred with transient water logging at the site early in the season.

Crown rot infection (added CR) did not significantly affect grain protein levels in any of the entries at this site in 2016.

Screening levels were very low across entries, but crown rot infection caused a small (0.5–1.3%), yet significant, increase in the level of screenings in the barley varieties Compass$^{\phi}$ and Commander$^{\phi}$, and the bread wheat varieties Coolah$^{\phi}$ and LRPB Spitfire$^{\phi}$.

Table 1. Yield and grain quality of varieties with no added and added crown rot – Merriwa 2016.

Crop	Variety	Yield (t/ha)		Protein (%)	Screenings (%)	
		No added CR	Added CR		No added CR	Added CR
Barley	La Trobe	4.53	4.06	8.4	0.9	1.1
	Spartacus	4.61	4.03	8.8	0.9	1.1
	Compass	4.29	4.01	8.4	0.4	1.0
	Commander	4.96	3.98	8.1	0.7	2.0
Durum	190873	3.56	3.45	8.6	0.4	0.4
	DBA Lillaroi	3.76	3.29	8.3	0.4	0.5
	Jandaroi	3.55	3.29	8.4	0.5	0.5
Bread wheat	Beckom	4.90	4.58	7.8	0.9	1.0
	Coolah	4.49	4.32	8.0	1.2	1.6
	LPB12-0494	4.70	4.16	8.0	1.8	2.1
	LRPB Spitfire	4.31	4.05	8.9	1.3	1.9
	LRPB Reliant	4.45	4.03	7.5	1.2	1.4
	Mitch	4.61	4.00	7.6	0.7	0.7
	EGA Gregory	4.44	4.00	7.8	0.6	1.0
	LRPB Lancer	4.05	3.96	8.8	0.6	0.6
	LRPB Flanker	4.65	3.79	7.7	0.7	0.9
	LRPB Gauntlet	3.88	3.71	7.8	0.7	0.8
	Suntop	3.92	3.70	8.0	1.5	1.5
	Sunguard	4.02	3.60	8.2	0.6	0.6
	Sunmate	4.16	3.60	8.2	2.2	2.1
Site mean		4.29	3.88	8.2	0.9	1.1
CV (%)		5.1		5.4	23.4	
l.s.d.		0.336		0.5	0.39	
P value		0.023		<.001	0.001	

Conclusions

Cereal crop and variety choice affected yield in the absence and presence of added crown rot inoculum, which differed by 1.41 t/ha and 1.30 t/ha, respectively between the best and worst entries. Only the bread wheat variety Beckom$^{(b)}$ provided a yield benefit (15%) over growing the susceptible bread wheat variety EGA Gregory$^{(b)}$ under high levels of crown rot infection at Merriwa in 2016. This could have maximised profit in this growing season, but will **not** reduce inoculum levels for subsequent crops because all winter cereal varieties are susceptible to crown rot infection. Winter cereal crop and variety choice is therefore **not** the sole solution to crown rot, but rather just one element of an integrated management strategy to limit losses from this disease.

Acknowledgements

This research was part of the project *National crown rot epidemiology and management program* (DAN00175), with joint investment by NSW DPI and GRDC. Thanks to Mark Campbell for providing the experiment site and Peter Matthews (NSW DPI) for helping to organise operations. Thanks to Chrystal Fensbo (NSW DPI) for grain quality assessments and to Jason Lowien (GrainCorp) for use of an NIR machine to determine grain protein levels.

Faba bean disease tolerance – Breeza 2016

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Key findings

- In a year with high rust pressure, fungicide application provided beneficial to all genotypes, even those with a good level of rust resistance.
- Several advanced breeding lines from the northern breeding program show promise, with high yield and large seed size combined with rust and chocolate spot resistance equal to or better than the current northern varieties.

Introduction

Rust is considered to be the most important faba bean disease in the northern region; breeding for rust resistance has been a high priority for the breeding program. No complete rust resistance is available within the faba bean germplasm pool, and although recently released varieties have improved rust resistance, they will still show disease under high inoculum pressure. Yield losses do not solely depend on the level of disease, but will also be influenced by the level of tolerance (the ability to compensate for the effect of the disease) of each genotype.

The experiment aimed to compare the performance of faba bean varieties and advanced breeding lines under different levels of rust pressure. Inoculations with greenhouse produced rust spores were applied early in the season to generate a high level of disease. Two fungicides registered for rust control in faba bean, mancozeb and tebuconazole, were used to provide low-disease level controls.

Site details

Location	Liverpool Plains Field Research Station, Breeza
Co-operator	Scott Goodworth
Soil type and nutrition	Self–mulching heavy clay
Rainfall	A total of 495 mm rainfall was recorded at the experiment site between sowing and harvest, which encouraged foliar disease development.
Experiment design	A split-plot design with three replicates was used with the two fungicides and control treatments as main plots and 12 faba bean genotypes as sub-plots.
Sowing date	27 April
Fertiliser	Nil
Plant population	Target 20 plants/m²
Weed management	Post-sowing/pre-emergent Terbyne® 1 kg/ha (terbuthylazine 750 g/kg) applied on 27 April
Insect management	Insect pressure was low and no insecticide was used.
Harvest date	21 November

Treatments

Varieties (12)

- Doza⁽ᴾ⁾ – released in 2008, classified MR–R (moderately resistant to resistant) to rust
- PBA Warda⁽ᴾ⁾ – released in 2012 and classified MR–R to rust

- PBA Nasma⍉ – released in 2015, large seeded and classified MR–R to rust
- IX474/4-12, IX486/7-6 and IX561f/4-2 and11NF001a-10 – advanced lines from the northern breeding program
- Fiesta VF– an old southern variety classified as S (susceptible) to rust
- PBA Samira⍉ – released in 2014, a southern variety, MS (moderately susceptible) to rust
- PBA Zahra⍉ – released in 2015 for southern regions, large seed and MS to rust
- AF09169 and AF11212 are both advanced lines from the southern breeding program

Fungicides

Either mancozeb 1 kg/ha (750 g/kg mancozeb) or tebuconozole 350 ml/ha (430 g/L tebuconazole) applied on 16 June, 1 August, 18 August and 9 September. NSW DPI research is covered under a permit to use off-label crop protection products and application rates on experimental plots (PER7250) and the applied rate was higher than the 145 ml/ha permit rate for tebuconazole on faba bean.

Table 1. Faba bean disease tolerance experiment, Liverpool Plains Field Station, 2016.
Genotype averages for disease scores (values within a column followed by same letter do not differ significantly, l.s.d. 5%).

Variety	Rust August	Stemphylium August	Rust (leaf) September	Rust (stem) September	Chocolate spot September	Leaf retention September
Doza	7.2[cd]	3.7[abc]	4.4[a]	4.1[a]	17.2[bc]	3.2[bcd]
PBA Warda	5.5[abc]	12.3[d]	5.2[ab]	5.7[ab]	17.1[bc]	3.3[de]
PBA Nasma	7.7[cd]	6.5[c]	6.6[abcd]	5.5[ab]	19.7[cde]	3.3[cd]
IX474/4-12	6.0[bcd]	4.0[abc]	5.8[abc]	5.3[ab]	18.4[cd]	2.9[abc]
IX486/7-6	4.1[ab]	3.7[abc]	4.8[ab]	4.2[a]	17.6[bcd]	2.8[a]
IX561f/4-2	10.7[ef]	14.3[d]	8.6[de]	7.4[bc]	20.0[cde]	3.3[cd]
11NF001a-10	2.8[a]	4.1[abc]	5.1[ab]	3.7[a]	13.0[a]	2.8[a]
Fiesta	17.4[g]	4.3[bc]	9.7[e]	9.3[c]	21.7[e]	3.7[e]
PBA Samira	12.4[f]	0.4[a]	7.1[bcd]	6.5[ab]	14.1[a]	2.9[ab]
PBA Zahra	8.7[de]	1.9[ab]	4.3[a]	4.6[a]	15.4[ab]	3.1[abcd]
AF09169	6.0[bcd]	0.7[ab]	6.6[abcd]	4.0[a]	21.6[e]	2.8[a]
AF11212	6.2[bcd]	29.6[e]	7.8[cde]	7.6[bc]	15.3[ab]	3.2[bcd]
Average	7.9	7.1	6.3	5.7	17.6	3.1
l.s.d. (5%)	2.9	4.0	2.2	2.3	2.8	0.4

Results

On 10 August plots were scored (% leaf coverage) for both rust (*Uromyces viciae-fabae*) and Stemphylium blight (*Stemphylium* spp.). On 27 September, plots were scored (% leaf coverage) for rust on stem, rust on leaf and chocolate spot (*Botrytis fabae*). On 30 September, plots were scored for leaf retention using a 1–5 scale (1 = no leaves dropped; 3 = 50% of the leaves dropped; 5 = >90 % of the leaves dropped).

Differences in rust resistance were clear among the genotypes with PBA Warda⍉ and the advanced breeding lines IX486/7-6 and 11NF001a-10 showing the highest level of resistance (Table 1). Tebuconazole was clearly superior to mancozeb in controlling rust (Table 2).

Table 2. Faba bean disease tolerance experiment, Liverpool Plains Field Station, 2016.
Treatment averages for disease scores (values within a column followed by same letter do not differ significantly, l.s.d. 5%).

Treatment	Rust August	Stemphylium August	Rust (leaf) September	Rust (stem) September	Chocolate spot September	Leaf retention September
Control	20.1[b]	10.0[b]	15.7[b]	14.1[b]	20.8	4.0[a]
Mancozeb	2.9[a]	8.1[b]	1.8[a]	0.8[a]	15.5	3.0[b]
Tebuconazole	0.7[a]	3.3[a]	1.4[a]	2.1[a]	16.5	2.2[c]
Average	7.9	7.1	6.3	5.7	17.6	3.1
l.s.d. (5%)	5.8	3.8	4.8	3.0	n.s.	0.5

The level of rust reduction from fungicide application was more successful with the rust susceptible lines than with the more resistant ones, resulting in a highly significant (P<0.001) genotype*treatment interaction (Figure 1). The fungicide application efficacy, especially tebuconazole, in controlling rust was demonstrated on highly susceptible lines such as Fiesta with rust severity reduced to very low levels.

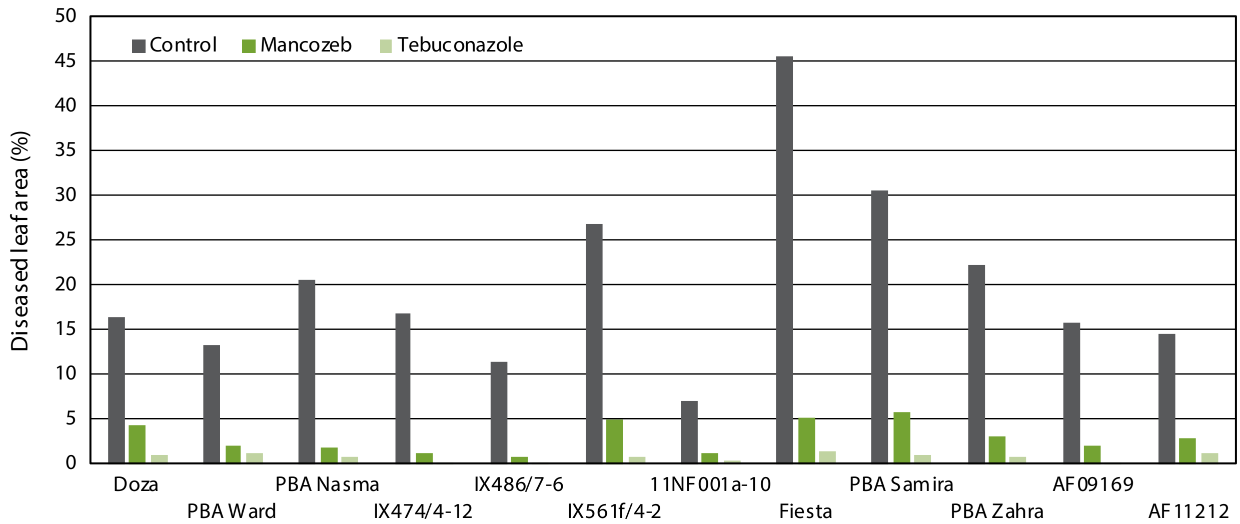


Figure 1. Faba bean disease tolerance experiment. Rust severity on 12 genotypes, control versus two fungicide applications, August 2016. l.s.d. (5%) for genotype*treatment averages = 5.0%.

The 2016 season was the first year in which high incidences of Stemphylium blight were noted in experimental plots and commercial fields of faba bean throughout the northern region. An unexpected high variation for Stemphylium blight severity was found among genotypes with PBA Warda⁽ᵇ, IX561f/4-2 and, especially, AF11212, showing a high degree of susceptibility (Table 1). Tebuconazole application resulted in a highly significant (P<0.001) reduction in severity (Table 2). As with rust, a significant interaction between fungicide applications and genotypes was found, as the reduction in blight severity was particularly visible in the highly susceptible genotypes (Figure 2).

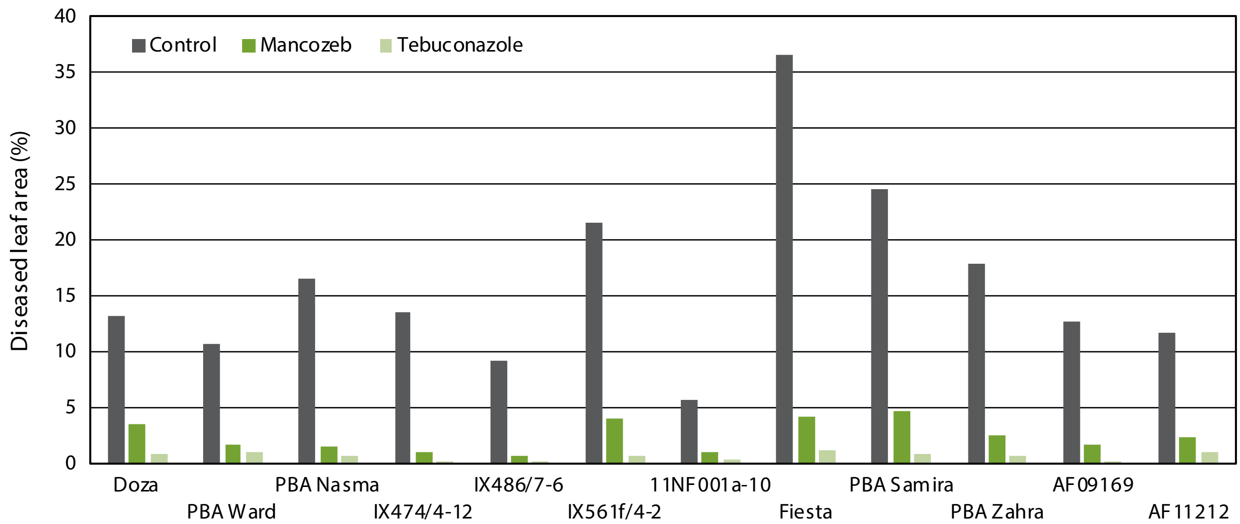


Figure 2. Faba bean disease tolerance experiment. Stemphylium blight severity on 12 genotypes, control versus two fungicide applications, August 2016. l.s.d. (5%) for genotype*treatment averages = 6.9%.

The late September rust scores show a similar pattern to the earlier readings with near complete protection from the disease from either mancozeb or tebuconazole, even in the most susceptible lines (Figure 3).

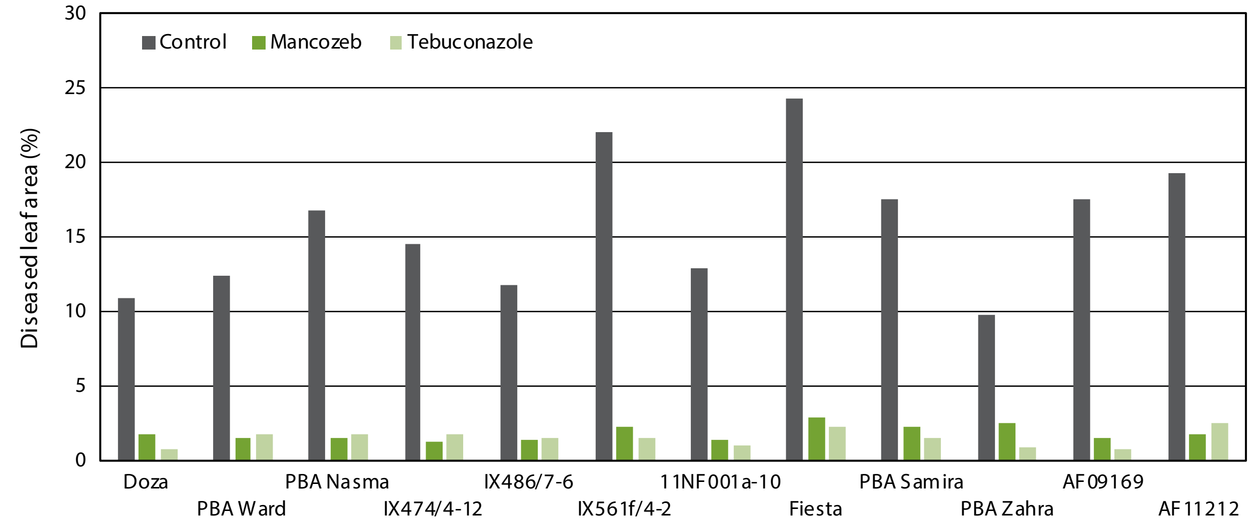


Figure 3. Faba bean disease tolerance experiment. Rust severity on the top leaves of 12 genotypes, control versus two fungicide applications, September 2016. l.s.d. (5%) for genotype*treatment averages = 3.9%.

Genotypes differed in chocolate spot scores with the northern advanced breeding line 11NF001a-10 showing a similar level of resistance as the best southern material (Table 1). Surprisingly, the difference between the control and the fungicide applications was not significant (Table 2) and no interaction between fungicide applications and genotypes was found.

Fungicide application, especially tebuconazole, had a positive effect on leaf retention (Table 2). The genotype ranking for leaf retention indicated the effect of rust on this trait (Table 1). As with rust, the fungicide effect was largest for the rust susceptible genotypes Fiesta and IX561f/4-2 (Figure 4).

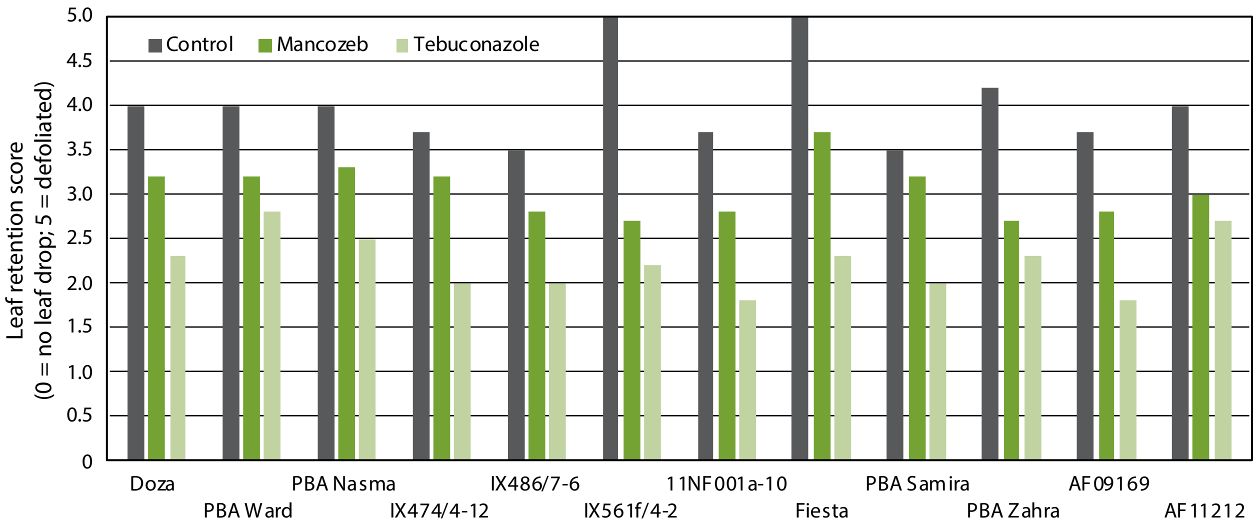


Figure 4. Faba bean disease tolerance experiment. Leaf retention score on 12 genotypes, control versus two fungicide applications, September 2016. l.s.d. (5%) for genotype*treatment averages = 0.6

Grain yield and seed size

The mancozeb and tebuconazole applications resulted in a yield increase over the control of 47% and 88% averaged over varieties respectively (Table 4). Genotypes differed greatly in yield with IF474/412, AF09169 and 11NF001a-10 the best performers (Table 3). The relatively good performance of the highly Stemphylium blight susceptible AF11212 was unexpected and could be an indication that the impact of Stemphylium blight on yield was relatively small.

No significant interaction was found between fungicide application and varieties for yield, which was surprising given the highly significant interactions found for rust severity scores. It appears that even highly rust resistant varieties benefit from fungicide applications. Phytotonic effects of fungicide applications in the absence of disease have been reported and might require further investigations.

The absence of an increase of seed weight after fungicide applications (Table 4) was equally surprising, given earlier experiments in which substantial seed weight increases were recorded when rust was controlled.

Conclusions

Genotypes differed in their susceptibility to rust, chocolate spot and Stemphylium blight, with one of the northern breeding lines (11NF001a-10) showing a level of chocolate spot and rust resistance equal to the best current commercial varieties. Fungicides were highly effective in reducing rust symptoms and improving leaf retention, but in this experiment had no effect on chocolate spot severity. Note that the permit for tebuconazole allows for only three applications of 145 ml/ha in commercial crops.

Table 3. Faba bean genotype tolerance experiment, Liverpool Plains Field Station, 2016
Genotype averages for yield components (values within a column followed by same letter do not differ significantly, l.s.d. 5%).

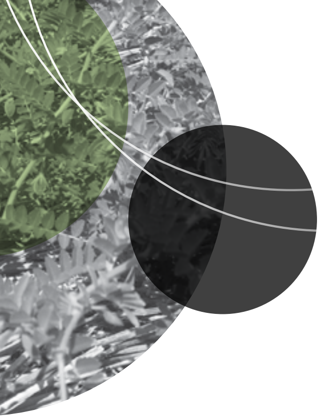
Variety	Yield (t/ha)	100 seed weight (g)
Doza	2.5[d]	54.7[a]
PBA Warda	2.4[cd]	60.1[bc]
PBA Nasma	2.4[cd]	67.5[f]
IX474/4-12	3.2[f]	66.4[ef]
IX486/7-6	2.9[ef]	63.0[cd]
IX561f/4-2	2.6[de]	63.9[de]
11NF001a-10	2.9[f]	60.7[bc]
Fiesta	1.3[a]	59.2[b]
PBA Samira	1.7[b]	69.3[f]
PBA Zahra	2.1[c]	76.4[g]
AF09169	3.0[f]	67.4[f]
AF11212	2.5[d]	64.1[de]
Average	2.5	64.4
l.s.d. (5%)	0.4	3.1

Table 4. Faba bean genotype tolerance experiment, Liverpool Plains Field Station, 2016.
Treatment averages for yield components (values within a column followed by same letter do not differ significantly, l.s.d. 5%).

Treatment	Yield (t/ha)	100 seed weight (g)
Control	1.7[a]	63.0
Mancozeb	2.5[b]	65.5
Tebuconazole	3.2[c]	64.7
Average	2.5	64.4
l.s.d. (5%)	0.3	ns

Acknowledgements

This research is part of the projects *PBA Australian faba bean breeding program* (UA00127) and *Northern NSW integrated disease management* (DAN00176), with joint investment by NSW DPI, NWLLS and GRDC. Thanks to Merv Riley and Ivan Stace for technical assistance.



Nutrition & Soils

Nitrogen response of six wheat and four barley varieties across two sowing dates – Nyngan 2016

Greg Brooke, Tracie Bird-Gardiner and Jayne Jenkins
NSW DPI, Trangie

Key findings

- The experiment was highly responsive to nitrogen application (N).
- Averaged across the two sowing dates, yield ranged from 0.89 t/ha in LRPB Dart(d) without applied N to 4.95 t/ha in LRPB Flanker(d) with the highest application rate of 160 kg N/ha.

Introduction

Nitrogen (N) is the nutrient needed in greatest quantity by grain crops. In winter cereal crops such as wheat and barley, N is important for determining both yield and grain protein levels. However, in lower rainfall environments, high soil N levels can contribute to 'haying off' in wheat when adequate moisture is not available to finish the crop. In the 2016 season at Nyngan, the site was waterlogged during mid to late winter. Below average spring temperatures, combined with both plentiful subsoil moisture and continued rainfall, allowed crops the chance to meet high yield potentials provided that N nutrition was adequate.

Site details

Location	'Folkestone', Nyngan
Co-operator	Kevin, Trevor and Michael Dutschke
Soil type and nutrition	See Table 1
Rainfall	A total of 450 mm rainfall was recorded from April to Oct 2016. The long-term average annual rainfall for Nyngan is 444 mm, which demonstrates how much wetter the 2016 growing season was in comparison.
Trial design	Ten varieties × 6 N rates × 2 sowing dates. Three replicates of each treatment blocked for sowing date with N rate and variety randomised within these blocks.
Fertiliser	70 kg/ha Triple Super at sowing.
Plant population	Target 100 plants/m^2
Weed management	Pre-sowing: Roundup CT 1.5 L/ha + Logran 38 g/ha In-crop: Axial 200 mL/ha plus Velocity, 1 L/ha
Insect management	Fastac® 125 mL/ha (alpha cypermethrin 100 g/L) to control cereal aphids.
Disease management	Radial®Fungicide (azoxystrobin 75 g/L + epoxyconazole 75 g/L) @GS32 and Prosaro (prothioconazole 210 g/L + tebuconazole 210 g/L) GS 39 targeting stripe rust prevention in wheat.

Harvest dates	31 October for SD1 and 15 November for SD2.

Table 1. Site soil chemical characteristics for 0–10 cm depth at Nyngan in 2016.

Characteristic	Depth (0–10 cm)
pH (1:5 $CaCl_2$)	5
Aluminium Exc. (meq/100 g)	0.065
Zinc (mg/kg)	0.76
Sulfur (mg/kg)	9
Phosphorus (Colwell) (mg/kg)	33
Organic carbon (OC) (%)	0.99
Nitrate + ammon. N kg N/ha (0–120 cm)	133

Treatments

Varieties (10)

Wheat (6): LRPB Dart⁽ᴰ⁾, EGA Gregory⁽ᴰ⁾, LRPB Flanker⁽ᴰ⁾, LRPB Lancer⁽ᴰ⁾, LRPB Spitfire⁽ᴰ⁾ and Suntop⁽ᴰ⁾

Barley (4): Compass⁽ᴰ⁾, Fathom⁽ᴰ⁾, LaTrobe⁽ᴰ⁾ and Spartacus⁽ᴰ⁾

Sowing date (SD)

SD1: 19 April 2016

SD2: 7 May 2016

Nitrogen rates

Urea pre-drilled 30 mm to side of plant row immediately before sowing at six rates 0, 20, 40, 40 + 40, 80,160 kg N/ha. The 40 + 40 treatment had 40 kg N/ha as urea applied at sowing and 40 kg N/ha as urea top-dressed at the end of tillering.

Results

Grain yield

There was a linear response across all varieties in grain yield to increasing rates of N application (r2 = 0.97) with the 160 kg N/ha rate yielding 2.8 t/ha more than the nil N application (data not shown). Optimum yield response to applied N (kg grain/ha for kg N/ha applied) was achieved from the 40 + 40 kg N/ha (26 kg/ha grain) and 80 kg N/ha (25 kg/ha grain) treatments. The 160 kg N/ha rate provided the highest overall yield, producing 17.9 kg grain/ha per kg N applied.

Fathom⁽ᴰ⁾ and Compass⁽ᴰ⁾ barley varieties yielded 0.1–0.3 t/ha more than La Trobe⁽ᴰ⁾ and Spartacus⁽ᴰ⁾. For the wheat varieties, LRPB Dart⁽ᴰ⁾ had a significantly lower yield than all other wheat varieties (Figure 1).

Protein

Nitrogen application treatments and variety affected protein levels. Averaged across the two sowing dates, the bread wheat variety LRPB Dart⁽ᴰ⁾ had significantly higher protein levels than all other wheat varieties, being above 10% in all N treatments (Figure 2). However, it was also the lowest yielding. In the bread wheats, the only other nitrogen treatments to exceed 10% protein were the LRPB Spitfire 40:40 split treatment and the 160 kg N/ha treatment for LRPB Lancer⁽ᴰ⁾, Suntop⁽ᴰ⁾, LRPB Spitfire⁽ᴰ⁾ and EGA Gregory⁽ᴰ⁾.

A minimum protein content of 9% (note that Fathom⁽ᴰ⁾ is a feed variety) is required for barley to receive malt classification. The only N treatments that produced greater than 9% protein in the barley varieties were the 40:40 split treatment in Fathom⁽ᴰ⁾, La Trobe⁽ᴰ⁾ and Spartacus CL⁽ᴰ⁾, and the 160 kg N/ha treatment in all four barley varieties (Figure 2).

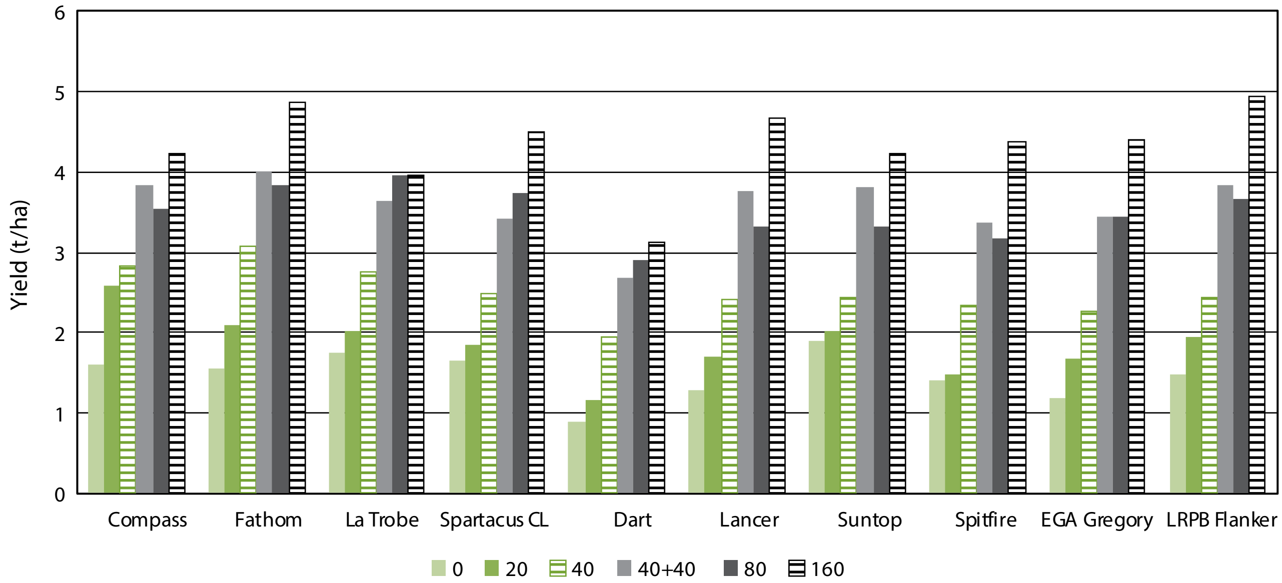


Figure 1. Average grain yield response across two sowing dates of six wheat and four barley varieties to six applied N (kg N/ha) treatments – Nyngan 2016. (L.S.D (P<0.05)) = 0.66 t/ha).

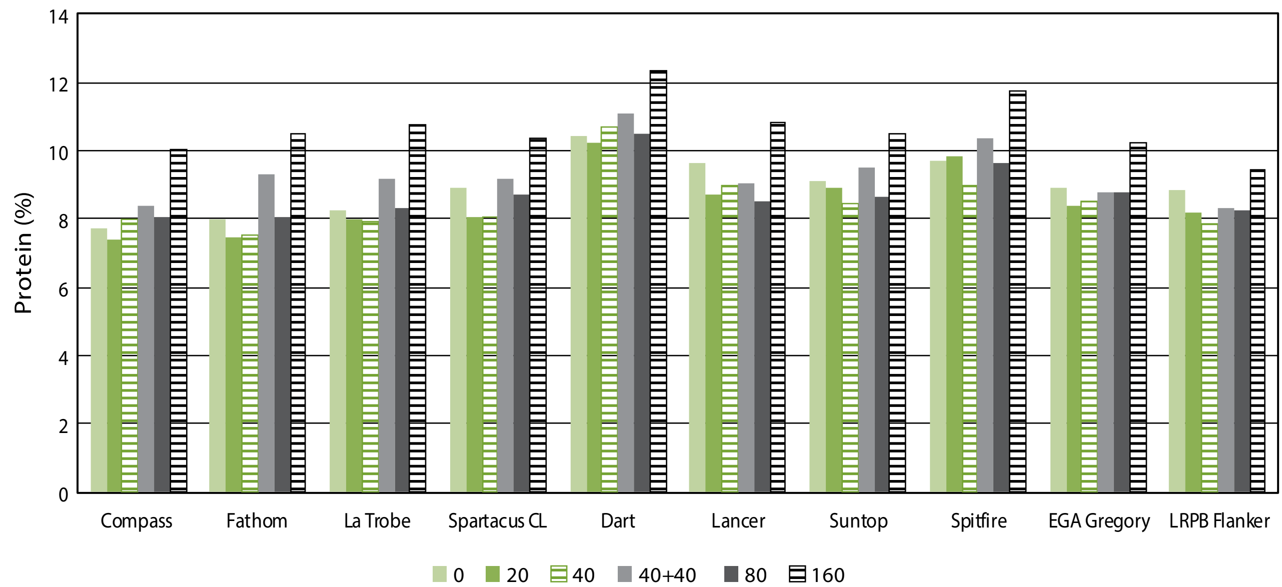


Figure 2. Average grain protein response (%) across two sowing dates to six nitrogen treatments – Nyngan 2016. (l.s.d. (P<0.05) = 0.79 %).

Conclusions

An extremely wet winter, low sunlight and low spring temperatures combined to produce an atypical season at Nyngan in 2016. In contrast, in a similar experiment conducted in the 2015 season at Nyngan that had a hard finish, all N rates above 20 kg N/ha led to a decline in yield and an increase in screenings of up to 50% in some varieties. Hence, these findings should be interpreted with caution but do highlight the value of higher N application rates in terms of both yield and protein achievement in seasons with more favourable growing conditions.

Acknowledgements

This experiment was part of the project *Variety Specific Agronomy Packages for southern, central and northern NSW* (DAN00167), with joint investment by NSW DPI and GRDC. Thanks to Dutschke family for providing the trial site at 'Folkstone'. Technical assistance provided by Rachel Hayden, Ryan Potts and Wayne Williams (NSW DPI) is gratefully acknowledged.

Faba bean fertiliser trial – Spring Ridge 2016

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Key findings

- Adding phosphorus (P) did not significantly increase yield or seed weight in the varieties PBA Warda⟮D⟯ and PBA Nasma⟮D⟯.
- PBA Nasma⟮D⟯ produced greater yield and seed size than PBA Warda⟮D⟯.

Introduction

This experiment aimed to study the effect of nitrogen (N) and phosphorus (P) application separately and in combination on the growth and yield of faba bean. A small amount of N at sowing might improve yield through faster establishment and groundcover. There is also little local data available on faba bean response to additional P.

Site details

Location 'Nowley', Spring Ridge

Co-operator The University of Sydney

Soil type and nutrition The experiment was undertaken on a known P-responsive vertosol

Site soil chemical characteristics for 0–15 cm depth at Nowley in 2016.

Characteristic	Depth (0–15 cm)
pH_{Ca}	7.7
Zinc (mg/kg)	1.5
Sulfur (mg/kg)	14
Phosphorus (Colwell) (mg/kg)	14
Organic carbon (OC) (%)	1.3
Cation exchange capacity (CEC) (meq)	48

Trial design A randomised split block design was used with variety as the main blocks, N as subplot and P as the sub-subplots; with three replications. Fertiliser treatments were applied immediately pre-sowing and seed was sown offset from fertiliser rows by 5 cm. Reflectance was measured on 25 July using an N Tech® Industries, Inc. Model 505 GreenSeeker Hand Held™ Optical Sensor Unit and a biomass cut was taken on 10 October at late podding. Grain samples from harvest were used to measure seed weight.

Sowing date 5 May

Plant population Target 20 plants/m^2

Weed management Post-sowing/pre-emergence: Terbyne® 1 kg/ha (terbuthylazine 750 g/kg) applied on 5 May
Post-emergence: clethodim 500 mL/ha (clethodim 240 mL/L) applied 15 July with mancozeb (see Disease management section below).

Disease management Targeting rust (*Uromyces vicia-fabae*), and chocolate spot (*Botrytis fabae* and *B.cinerea*):

- Dithane™ @ 2 kg/ha (mancozeb 750 g/kg) applied on 4 July
- Dithane™ @ 1 kg/ha (mancozeb 750 g/kg) applied on 15 July
- Unite® 720 @ 1.5 L/ha (chlorothalonil 720 g/L) applied on 2 August
- Spin flo® @ 500 mL/ha (carbendazim 500 g/L) applied on 2 September

Insect management	*Heliothis* sp. pressure was low and no insecticides were applied.
Harvest date	21 November

Treatments

Varieties (2)	PBA Warda[⊕], PBA Nasma[⊕]
Nitrogen	0 and 10 kg N/ha applied as urea
Phosphorus	0, 5, 10 and 20 kg P/ha applied as triple superphosphate

Results

Establishment

Faba bean establishment of 19 plants/m^2 was achieved, close to the target (20 plants/m^2) and there were no significant (P<0.05) differences in establishment due to N, P or variety.

Reflectance and dry matter

No significant differences (P<0.05) in reflectance or biomass due to N, P or variety occurred, indicating that plant growth was not influenced by the treatments applied.

Grain yield and seed weight

Overall, PBA Nasma⊕ gave significantly higher (P<0.05) yield and seed size than PBA Warda⊕ (Table 1) and N application unexpectedly reduced yield, with zero N plots yielding significantly (P<0.05) more (3.6 t/ha) compared with plus N plots (3.2 t/ha). Overall, adding P made no significant difference to yield (Table 2), although there was a trend to higher yield with the highest (40 kg/ha) P application.

Table 1. Yield and seed size of two faba bean genotypes at Nowley in 2016.

Variety	Yield (t/ha)	Seed size (g/100 seeds)
PBA Nasma⊕	3.6^{a*}	80.1^{a*}
PBA Warda⊕	3.1^{b}	64.8^{b}

*letters denote significance at P<0.05

Table 2. Phosphorus application and yield across two genotypes of faba bean at Nowley in 2016.

Phosphorus applied (kg/ha)	Yield (t/ha)
0	3.3^{a*}
5	3.4^{a}
10	3.3^{a}
20	3.6^{a}

*letters denote significance at P<0.05

Conclusions

In this experiment, additional P did not increase yield, however, on a lower P site, a positive response to P might occur. The reduction in yield caused by adding N might be due to reduced nodulation in N-treated plots, although nodulation was not measured in this trial. The greater yield and seed size of PBA Nasma⊕ compared with PBA Warda⊕ supports other experimental data.

Acknowledgements

This research was part of the project *Northern pulse agronomy initiative – NSW* (DAN00171) with joint investment by NSW DPI and GRDC. Thanks to Michael Nowland, Gerard Lonegran, Peter Perfrement and Matt Grinter, NSW DPI staff, for technical assistance.

Decisions used by NSW grains industry advisers to determine nitrogen fertiliser management recommendations

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Key findings

- Nitrogen (N) decision making requires a good understanding of background soil and plant science, and soil test interpretation.
- Training for new agronomists needs to be a priority issue.
- Senior NSW agronomists identified crop yield expectation as guided by soil moisture at sowing (or at the time of N decision making) as the most important determinant of N fertiliser requirement.
- Further research is needed to increase the understanding of how management practices affect potentially large gaseous N losses.
- Changing from legume pasture-crop sequences to continuous cropping in many central and southern areas of New South Wales is posing new questions for managing N supply. The absence of N-fixation by pasture legumes is seen as a substantial loss of N-buffering capacity.
- Despite most advisers choosing soil testing as a key approach for determining N fertiliser required, many of their clients had a lower confidence in soil testing, citing 'high perceived variability in soil nitrate results in the lead up to sowing'.

Introduction

There is concern that grower and advisor decisions related to nitrogen (N) management in field crops are often inaccurate, despite the range of decision tools available to inform and assist. Factors that potentially contribute to sub-optimal decisions on N management include variable rainfall patterns, climate change, declining soil organic matter, using no-tillage, and a declining frequency of legumes in farming systems. A survey was conducted to improve our understanding of how advisers make decisions relating to field crop N nutrition in order to better target assistance to Australian grain growers and their advisers to reduce the uncertainty and financial risk associated with N management.

The survey was conducted across Australian grains regions to better understand the knowledge, perceptions, current practices, and the assumptions underpinning the practices of grain industry advisers when providing advice on N management. This information, combined with a literature review of Australian research into N processes in cropping soils, will help identify knowledge gaps and develop new research plans for grain growing areas.

This paper presents the findings from the NSW component, which included an on-line survey of grains industry advisers and subsequent detailed interviews with a state-wide selection of selected senior respondents to further examine their responses.

Survey details

A multiple choice survey, based on common questions developed by the national project team, was used to gauge the practices of grains consultants. Hardcopy surveys and email requests were sent out to advisers throughout New South Wales from September to November 2015 using the online portal, Survey Monkey. In total, 132 advisers responded from across the NSW grains area. Of these, 105 provided their postcode, which enabled the geographical spread of respondents to be mapped (Figure 1). Forty seven percent of respondents were from the northern region, 20% from central and 33% from southern NSW. Given that each adviser represents a client base, the survey results encapsulate advice given to a large cross-section of the NSW grains farming sector.

In addition to the survey, more detailed phone interviews were conducted for 45–70 minutes with 11 senior advisers, grouped by three regions within the state: northern, central and southern NSW. During the phone interviews, the original survey questions were revisited, with the responses explored further using additional open questions and pre-determined prompts.

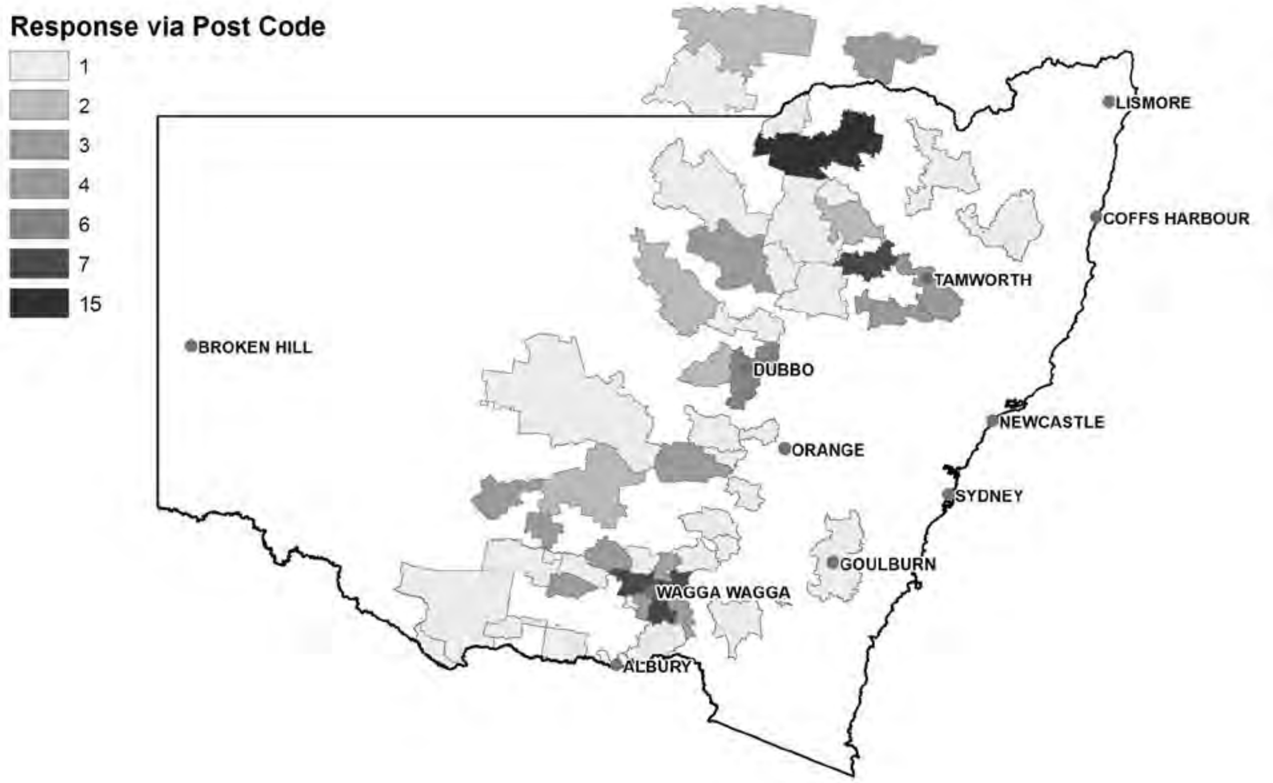

Figure 1. The geographical frequency and distribution of survey respondents by region.

Results

- Soil moisture at sowing (or at the time of N application decision-making) was identified as the most important determinant of N fertiliser requirement by nine of the 11 senior agronomists interviewed. Other factors considered important included: seasonal conditions, crop rotation, soil testing, financial risk, in-season crop assessment and previous paddock history.
- Respondents used decision support systems (DSS) for some of their decision making. Several advisers cited using DSS tools to help them understand issues and challenge thinking in certain instances, with the learning from this experience then applying it elsewhere. Examples of DSS used in northern NSW included SoilMate™ (Back Paddock Company) and N Balance (Herridge 2011). The John Angus N model/spreadsheet was similarly well respected and used by senior advisers in southern NSW. Yield Prophet was used by several senior advisers (mainly in southern NSW), primarily for helping to develop more accurate yield estimates based on soil water present at the time of decision making. Good soil characterisation was considered core to this system's accuracy.
- Senior advisers gained their knowledge from leading experts by attending GRDC Updates, formal training events and personal contact, as well as experience with their own clients. There is an ongoing need for adviser access to expert advice, plus the availability of detailed and well-delivered training targeted to advisers' needs.
- Senior advisers reported that a client's attitude to risk influences their N recommendation, with more conservative growers aiming for a lower input/lower risk system. In some instances, the amount of N applied is limited by available funds rather than a cost/benefit estimate. However, in the higher yielding, more reliable cropping zones of the state, advisers recommend applying higher rates of N fertiliser to maximise long-term profit, and growers generally follow this advice.
- N contribution from legumes is considerable in southern NSW where long pasture phases, dominated by lucerne, are often an integral part of the farming system. However, in central western NSW, farmers are moving away from pasture ley mixed farming to continuous

cropping. Advisers in the centre and north of the state highlighted the low contribution of N from crop and pasture legumes in these areas as a major constraint to production.

- Most advisers believe they have a very good understanding of the mechanisms behind their approach to N recommendations and factors such as mineralisation rates, yield, N and protein budgeting. As a result, most respondents felt their recommendations were generally reliable with the occasional failure when seasonal conditions were contrary to predictions, as occurred in the 2015 season.
- Most advisers felt that their N fertiliser recommendation needed to be within 10–15% of yield potential, and that their prediction of yield potential needed to be within 10–25% of the actual yield. Greater accuracy is not possible due to the many variables affecting yield and the inherent variability in parameters measured or estimated through rules of thumb.
- Soil tests were considered moderate to very important, with testing often used as a tool to help determine recommendations. Senior advisers said it was uneconomic to test as rigorously as science required, and moreover a significant number of growers had confidence issues with soil testing, with perceived high variability in soil nitrate results often reported in the period before sowing. Northern region advisers stratified soil tests by depth increments and were likely to carry out soil testing earlier in the fallow period than their southern counterparts, as N fertiliser is more likely to be applied pre-sowing in this region. In southern NSW, testing is conducted nearer to sowing as N is mostly applied post-sowing.
- Eighty percent of advisers indicated that they account for pre-sowing mineralisation in their recommendations, with 70% also accounting for in-crop mineralisation. Estimates of N mineralisation were usually based on rules of thumb derived from years of research and practical on-farm experience.
- When making recommendations, 86% of advisers accounted for how efficiently plants absorb N, with interviewed advisers commonly using a factor of 50% conversion efficiency of N fertiliser to grain N.
- N losses (leaching or gaseous) were accounted for by 40% of advisers. The understanding of gaseous N losses was better in northern NSW, where research over the past few years had been well publicised, than in southern NSW where no recent field work had been conducted.
- In the online survey, denitrification as di-nitrogen gas (N_2) was considered the major source of N loss by 40% of advisers, with a further 31% of respondents stating leaching and 23% stating ammonia volatilisation as the cause for losses from the system. Greater emphasis was placed on denitrification as the key loss pathway in interviews with senior advisers. However, as denitrification losses were generally associated with significant waterlogging events that were difficult to predict and sporadic in most regions, losses due to these pathways were generally seen as outlier events and not considered in N budgeting.

Conclusions and recommendations

- Senior advisers highlighted the importance of quality training in N decision-making, understanding the background soil and plant science involved, and soil test interpretation for the next generation of agronomists. They supported the availability of training courses that included representation from highly experienced local agronomists.
- The understanding of gaseous N losses requires further research, development and extension to the grains industry. Recent field research in the north was limited in scope and produced challenging outcomes that are already leading to large practice changes for when and how N fertiliser is applied. Further research and development work is warranted to answer more of the practical questions growers and advisers are asking in regards to losses associated with certain alternative practices.
- The northern NSW results on N loss pathways are less relevant to advisers in the central and southern NSW regions where N application timing, soil type and climatic differences are quite different from the dominant medium–heavy clay soils of the north. New N loss research is recommended for the lighter-textured soils in regards to the potential for N volatilisation losses from surface N application. Economic outcomes from the various

strategies being practiced are also needed. Nitrogen loss research should focus less on expensive slow-release products and more on optimising results from urea, the cheapest N source.

- Research into better soil water measurement was highlighted as a priority area, especially given the importance all advisers place on knowing this when making expensive N-fertiliser decisions for a coming cropping season. Zonal management within paddocks is not possible with single site characterisations, so atypical areas of paddocks are over or under-fertilised.
- Applying N fertiliser early, ahead of a winter cropping season, is a well-established practice in the northern grains region. However, what is not known is how well the pre-applied N might be protected from denitrification resulting from later flooding events. Greater knowledge on specific N use within the profile during the cropping season would assist with decisions related to the accessibility of late-applied N for plant uptake.
- State-wide, agronomists highlighted N mineralisation as an area for greater understanding with regards to the differences caused by climatic conditions, especially rainfall. Better understanding of the N produced from both native organic matter and recent legume pasture residues was also requested.
- There are several useful decision-support tools currently available, with the suggestion to combine the best points of each into one package, preferably available as an app with grower-friendly reports.
- Farmer don't have confidence in the accuracy of pre-sowing soil nitrate testing results. This might be related to a range of factors including poor sampling methods, incorrect sample handling, insufficient sample numbers, inadequate service from laboratory analysts, or inaccurate interpretation of the results. Soil testing is often regarded as an expensive option, with some advisers looking for quicker, more cost-effective methods for estimating soil mineral N.
- Some senior advisers see variety-specific N management packages as key areas for continued research funding, as results from some new varieties have been quite different in terms of N uptake and protein outcomes.

Reference

Herridge DF (2011). *Managing legume and fertiliser N for northern grains cropping*. (Grains Research and Development Corporation: Kingston, ACT, Australia).

Acknowledgements

This survey and follow-up interview series was part of the project *Organic matter and nutrient availability* (UQ00079), a collaborative project between state agencies and universities in Queensland, NSW, Victoria and Western Australia with joint investment by GRDC. Special thanks to Fiona Pearson (NSW DPI) for transcribing the hard copy surveys, to Georgia Rose and Erica McKay (ICAN) for collating the survey data and transcribing the interviews, and to Helen Squires (NSW DPI) for producing the map.

Soil nitrous oxide emissions in irrigated cotton are reduced by nitrification inhibitors applied with pre-plant anhydrous ammonia

Graeme Schwenke and Annabelle McPherson
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Key findings

- N_2O emissions at the Gunnedah site were approximately 10 times higher than at the Emerald site, due to the wet soil conditions and high pre-season rainfall at Gunnedah which led to denitrification of N from pre-season anhydrous ammonia application.
- Two nitrification inhibitors, DMPS ("Big N-sure®", Incitec Pivot Fertilisers) and nitrapyrin ("N-serve®", Dow AgroSciences) directly injected into anhydrous ammonia during pre-plant N application delayed the conversion of applied ammonium in the soil to nitrate for a period of 2–3 months.
- At the Gunnedah site, cumulative N_2O emitted was reduced by 86% (DMPS) and 65% (nitrapyrin), compared to untreated ammonia.

Introduction

This experiment aimed to assess the efficacy of two nitrification inhibitors, 3,4-dimethylpyrazole (DMP) and nitrapyrin, when applied directly into the anhydrous ammonia stream during pre-plant nitrogen (N) application for commercial irrigated cotton production. Pre-plant N fertiliser application produces a large pool of mineral N in the soil that is at risk of loss through nitrate-denitrification, a process that produces nitrous oxide (N_2O) – a greenhouse gas. Nitrification inhibitors restrict the conversion of ammonium to nitrate for a period of up to several months, thus reducing the nitrous oxide emissions during the pre-sowing and early crop establishment phase of irrigated cotton production. Currently, no nitrification inhibitors are commercially applied with anhydrous ammonia in Australia. This experiment investigated the potential for two inhibitors, nitrapyrin (N-Serve® from Dow Agrosciences, used commercially in USA) and DMPS (Big N-sure® from Incitec-Pivot, not used before with anhydrous ammonia) to reduce nitrous oxide emissions from soil.

Nutrition and soils

Site details

Locations	'Barwin' (Emerald) and 'Ruvigne' (Gunnedah)
Co-operators	Ross Burnett (Emerald), Rod Smith (Gunnedah), Incitec-Pivot Big-N team
Soil type and nutrition	Black Vertosols at both sites. Soil (0–30 cm) at Emerald was 42% clay, 44% sand, 14% silt. The profile had 34 kg N/ha of mineral N to 90 cm before N application. Soil (0–30 cm) at Gunnedah was 65% clay, 9% sand and 26% silt, and also had 34 kg N/ha in the profile to 90 cm when sampled at the conclusion of the previous cotton crop in late April 2016.
Rainfall and irrigation	At Emerald, there was 10 mm of rain during the 10-day pre-plant period between N application and sowing, then another 195 mm rainfall during the cropping season from sowing to harvest. The crop was irrigated 8 times including once pre-plant. A total of 7.375 ML/ha was applied. At Gunnedah, there was 280 mm of rain during the 69-day pre-plant period between N application and sowing, then another 216 mm rainfall during the cropping season from sowing to 1st February 2017. The crop was irrigated a total of 8 times. Because of the wet pre-season, no pre-plant or post-plant flush up irrigations were applied.

Trial design and treatments

Randomised complete block design with three treatments (T1 = ammonia, T2 = ammonia + DMPS [Big N-sure®], T3 = ammonia + nitrapyrin [N-serve®]) and three replications. A Raven SideKick Pro direct injection system was used to apply nitrification inhibitor at a rate of 2.5 L/ha (for both products) into the anhydrous ammonia stream at the supercooler unit before the distributor.

At Emerald, the pre-plant N rate was applied at 150 kg N/ha, followed by 150 kg N/ha as a urea side-dress just prior to the second irrigation. We used normal urea to side-dress T1 and T3, and DMPP-coated urea [ENTEC®] to side-dress T2. There was no equivalent nitrapyrin-coated urea product available to use in T3. The pre-plant ammonia was injected into the plant bed to a depth of 30 cm at a distance of 25 cm from the plant row on both sides of the plant bed. The side-dressed urea was applied at a depth of 5 cm on only the irrigated side of the plant bed, then immediately followed by cultivation.

At Gunnedah, the pre-plant N rate was 300 kg N/ha. No in-crop N application was planned, but the experimental area was inadvertently top-dressed with 75 kg N/ha as broadcast urea late in the vegetative growth period. The pre-plant ammonia was applied using a delta-T applicator centred on the middle of the non-irrigated furrow. Approximately 42.5% of the N is applied 9 cm either side of the mid-line as super-cooled ammonia (liquid), with the remaining approximately 15% of the N applied as vapour in the centre of the furrow.

Nitrous oxide measurements

Nitrous oxide emissions were measured during 5 (Emerald) and 6 (Gunnedah) separate 7–14 day-long campaigns with samples collected 1, 2, 4, 7 and sometimes also 10 or 14 days after a significant rainfall or irrigation event. Four manual chambers within each of the 9 plots per site were sampled at 0 and 60 minutes after sealing the chamber with a gas-tight lid. Samples were analysed by a laboratory gas chromatograph.

Sowing dates and varieties

The Emerald site was sown with Sicot 746B3F on 20 August 2016. The Gunnedah site was sown with Sicot 748B3F on 6 October 2016.

Harvest date

Cotton picking at Emerald was on 13 February 2017. Picking at Gunnedah was not yet done at the time of writing.

Results

Trial 1. Emerald

In general, N_2O emission rates were low throughout much of the season, with the first irrigation causing only a few temporary and highly variable emission peaks in treatment 1 (ammonia control). There was almost no response to the 21.8 mm rainfall event at the end of September 2016. Side-dressed urea followed by irrigation increased N_2O fluxes for at least 4 days in treatments 1 and 3, which had standard urea applied. Treatment 2, side-dressed with DMPP-coated urea, showed little N_2O loss during the same period. Further irrigations also produced N_2O emission responses, with some highly variable results from the irrigated side of the hills where the side-dressed urea had been applied.

The net result of these manual chamber measurements is shown as a cumulative emission of N_2O in Figure 1. Sampling in short campaigns meant that there were gaps in the timeline, but losses during these gaps would have been minimal based on the low N_2O fluxes measured at the end of each event. From pre-plant N application until side-dressing, both inhibitors kept total losses of N_2O to a minimum compared to the untreated ammonia control (T1). Cumulative N_2O was reduced by 77% (both inhibitors), compared to untreated ammonia. After the side-dressing, T1 and T3, which received untreated urea, continued to increase in N_2O loss while the DMPP-coated urea kept emissions to a minimum until the final measurement event when a single high flux in one replicate plots of T2 increased the average cumulative nitrous oxide loss for that treatment. The DMPP-coated urea reduced N_2O emission after side-dressing by 27%, compared to untreated urea. The untreated urea following the nitrapyrin (T3) appeared to increase N_2O emitted by 99% during this period, although the high variability of results meant that differences were not statistically significant.

As a proportion of the N applied, the seasonal losses were low, at only 0.2% (T1 and T3) or 0.09% (T2) of the N applied.

There were no significant impacts of the inhibitors on cotton lint yield at the Emerald site, as assessed by hand biomass cuts (data not shown).

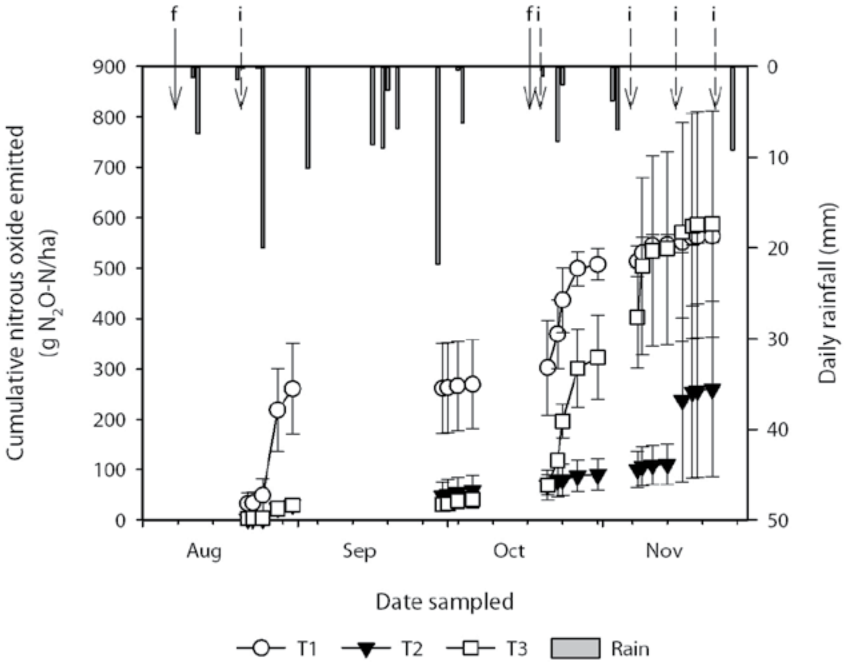

Figure 1. Cumulative nitrous oxide emissions from the Emerald experiment as influenced by treatment, rainfall and irrigation. Solid arrows at the top indicate dates of N application (f). Irrigation events within the measurement period are shown as dotted line arrows (i).

Trial 2. Gunnedah

Both inhibitors proved to be highly effective at maintaining much of the applied pre-plant N as ammonium in the soil for at least two months after application (Figure 2), compared to the control treatment (T1) where the mineral N was mostly found in the nitrate form by late September. By December, nitrate in T1 had declined to much lower levels, while in T2 and T3, nitrate concentrations were still high, especially in the fertilised furrow position.

During the first two months after pre-plant N application, intense rainfall events on an already wet soil led to waterlogging in the paddock and some very large daily fluxes of N_2O from T1, the untreated control. The effectiveness of the nitrapyrin appeared to have worn off by the time of the post-planting rainfall in October (T3), whereas the DMP inhibition (T2) continued until the first irrigation.

The cumulative N lost as N_2O (during the measurement periods only) is shown in Figure 3, with clear treatment differences. Total N_2O emissions for the overall season would have been higher, particularly in the untreated control (T1), as measured daily fluxes were still high at the end of most 7-day sampling campaigns. In total, DMPS reduced measured nitrous oxide emissions by 86% and nitrapyrin by 65%, compared to anhydrous ammonia applied without any nitrification inhibitor.

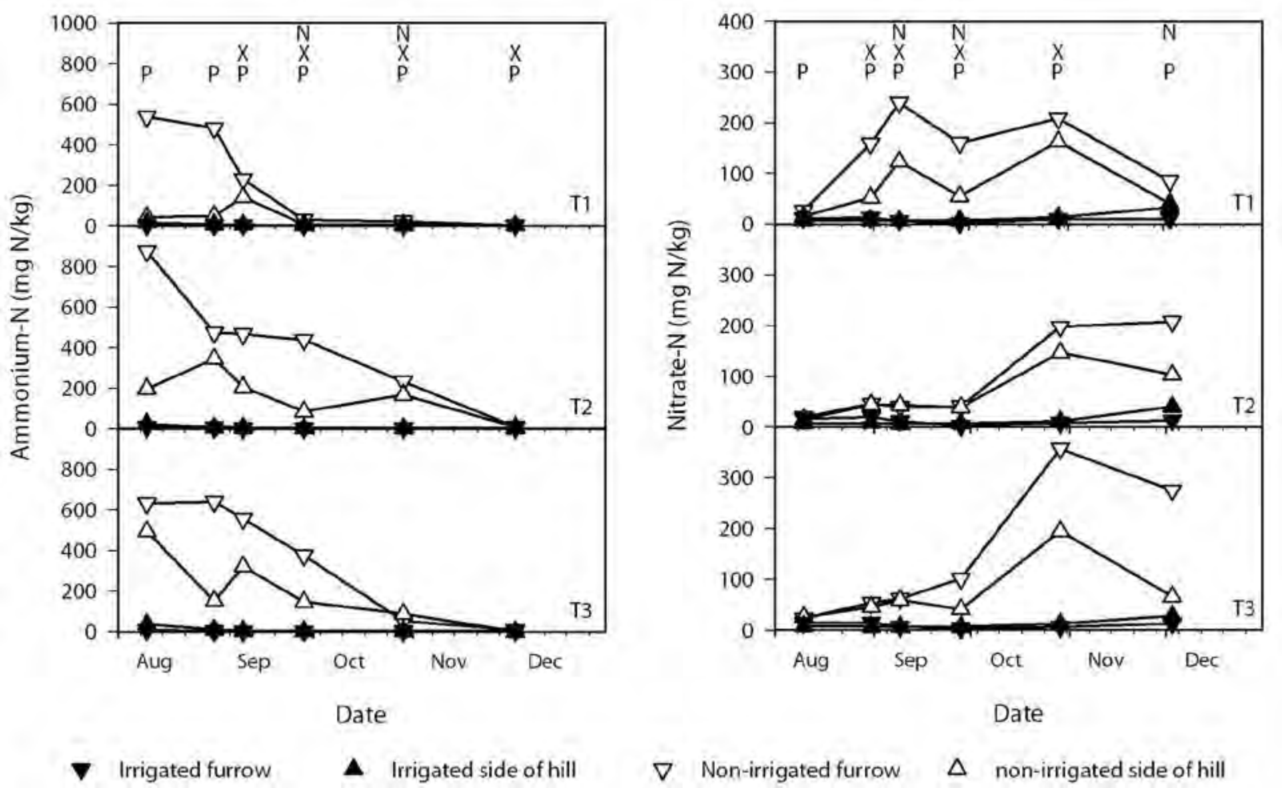

Figure 2. Surface soil (0–10 cm) ammonium-N (left) and nitrate-N (right) concentrations at four positions within each treatment at the Gunnedah trial. Letters above a sampling date indicate significant N treatment (N), chamber position (P), and N × P interactions (X), and apply to all three graphs in each column.

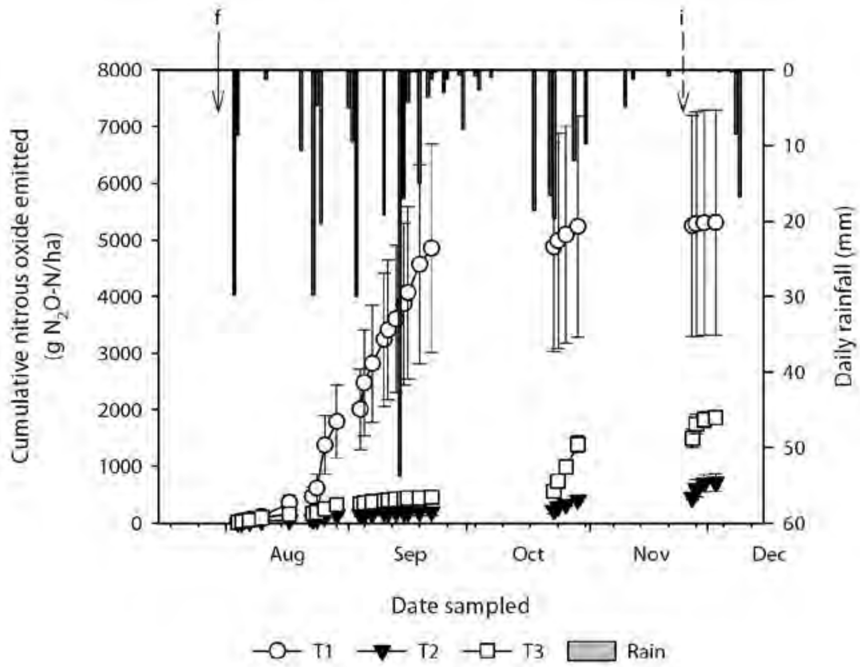

Figure 3. Cumulative nitrous oxide emissions from the Gunnedah experiment as influenced by treatment, rainfall and irrigation. Solid arrows at the top indicate dates of N application (f). Irrigation events within the measurement period are shown as dotted line arrows (i).

Does the prevention of N loss by using these products affect crop production? We attempted to answer this at Gunnedah by soil coring to 90 cm depth just prior to sowing. While the results appeared to show that the inhibitor treatments had reduced large losses of mineral N (data not shown), the treatment variability was too high to demonstrate statistically significant treatment differences. The definitive proof of any treatment effects would be observed as a plant productivity response, but inadvertent top-dressing of the trial area prevented any conclusive outcome of these inhibitors on crop performance and economic benefit. Despite this, both products demonstrated a clear environmental benefit on significantly reduced N_2O emissions.

Conclusions

In a season such as that experienced at the Emerald 2016–17 site, there were only minor environmental benefits from using a nitrification inhibitor in conjunction with anhydrous ammonia. However, these experimental conditions may not be typical as pre-plant fertiliser is usually applied earlier in the year at Emerald than it was at this site. A longer period of time between pre-plant application and plant establishment would provide greater opportunity for N_2O losses to occur, although the potential for heavy winter rainfall tends to be low in the Emerald region. While both inhibitor products clearly reduced emissions during the first two measurement periods, it was apparent that the effectiveness of these products had dissipated by the time of the second irrigation. The additional inhibitor application with the side-dressed urea boosted the N_2O reduction period for the DMPP treatment, while the application of untreated urea to the other treatments allowed further losses matching those of the untreated control after the initial pre-plant N application.

The 2016–17 Gunnedah experiment provided the perfect testing conditions for nitrification inhibitors as the soil was very wet at application, and received frequent heavy rainfall during the next 3 months. These inhibitors were designed to retain mineral N from applied N fertiliser in the soil during periods of excessive rainfall that may otherwise lead to large losses of nitrate N through denitrification and leaching. Leaching occurs through downward movement of nitrate with water in the soil, but we found no evidence of this having occurred in the soil core samples we took just prior to sowing. For heavy clay soils such as this one at Gunnedah, denitrification of soil nitrate during periods of anaerobic soil conditions is the most likely major N loss pathway. The results of the gas sampling campaigns highlighted the almost complete mitigation of N_2O emissions during this period by adding nitrification inhibitors. The Big N-sure® inhibitor appeared to remain active for longer in the soil than the N-serve®.

Acknowledgements

This experiment was part of the project *Determining optimum nitrogen strategies for abatement of emissions for different irrigated cotton systems* (AOTG14013; 2013–17), with joint investment by NSW DPI and DAWR, and administered by CRDC. Thanks to Ross Burnett and Rod Smith for providing the experimental sites and for applying the anhydrous ammonia and urea in field, and to Amanda Noone for carrying out the field work at Emerald, Pete Perfrement, Tim Grant and Wayne McPherson at Gunnedah. Technical assistance with the application of both inhibitors was provided by the Incitec-Pivot Big-N team and is gratefully acknowledged. Incitec-Pivot provided the Big N-sure® inhibitor and ENTEC®-urea, and Dow Agrosciences provided the N-serve® inhibitor. All soil and plant N analyses were carried out by Clarence Mercer in the ISO9001-accredited laboratory at Tamworth Agricultural Institute, NSW DPI.

Factors driving nitrous oxide emissions from uncropped (head ditch and tail drain) areas of irrigated cotton fields after water-run urea application

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[1]NSW DPI, Tamworth, [2]NSW DPI, Narrabri

Key findings

- A soil and sediment survey of 10 irrigated cotton paddocks across four cotton-growing valleys revealed the tail drain sediments were enriched in organic carbon (1.03% ± 0.05) and nitrogen (0.11% ± 0.01) compared with head ditch soils (0.73% ± 0.07 for carbon and 0.08% ± 0.01 for nitrogen) of the same paddocks. Nitrate-nitrogen and dissolved organic carbon analyses showed similar trends.
- After irrigation, tail drain samples tended to release more nitrous oxide compared with head ditch samples. Emission rates were linked to the pre-irrigation mineral nitrogen concentrations of the soil/sediments.
- These non-cropped areas, representing up to 2% of the paddock area, are a significant source of nitrous oxide emission per unit area of farm as they retain high soil moisture and nutrient concentrations in the absence of plants.
- Nitrous oxide emission calculations for cotton farming systems should incorporate the emissions from head ditch and tail drain sections of the irrigation network.

Introduction

Agricultural intensification has led to large scale, off-farm environmental impacts (Drinkwater & Snapp, 2007). One of the direct effects is on the global nitrogen (N) cycle and synthesis of nitrous oxide (N_2O) from reactive N in the soil. Land management practices, in conjunction with climate, fertiliser and water management practices, can significantly affect N_2O emissions from agricultural soils. Consequently, research to quantify the N_2O fluxes from various cropping systems, including cotton, has attracted great attention (Grace, 2016). Previous research on N_2O emissions has focused on cotton farm cropping zones and indirect emissions from irrigation water (Macdonald, Rochester & Nadelko 2015; Grace et al., 2016). The non-cropped areas in irrigated cotton farms can account for approximately 2% of the paddock area. The fertiliser N applied or leached into these zones can contribute to higher levels of mineral N than in the cropping field where growing plants deplete the applied N. The potential contribution from uncropped zones (head ditch and tail drain) to overall N_2O emissions in irrigated cotton production systems in Australia has not yet been quantified. In this laboratory study, we have simulated the irrigation and water-run urea application in soil and sediments to determine the N_2O emissions from the uncropped zones of cotton farms.

Site details

Location	Soil and sediment samples were collected from 10 cotton farms across four cotton-growing valleys (Namoi, Gwydir and Macquarie in NSW, and Central Highlands in QLD).
Soil properties	Table 1 details the sediment sample soil properties collected from cotton farms to be used in the simulation study.

Trial design

A soil incubation experiment was conducted whereby incubation chambers (150 mm diameter × 150 mm height) were filled with 2 kg of dried, ground, soil/sediment (<5 mm), allowing enough space for water to be applied. Treatments consisted of 10 farms × 2 locations (head ditch, tail drain) × 2 irrigation water treatments (water only, water-run urea) × 4 reps = 160 chambers. For the added-urea treatments, 5 kg N/ha was added to the tail drain samples and 30 kg N/ha added to the head ditch samples. This was to simulate a typical water-run urea application in the field. Both water only and water-run urea treatments included 10 mg/L of dissolved organic carbon (DOC), applied as glucose, to simulate the DOC typically found in irrigation water. All chambers were set up in an airconditioned room set to 25 °C. After the water was added, chambers were periodically capped with lids (1, 2, 4, 7, 14 days after water added) and fluxes of nitrous oxide were measured by manual gas sampling through a rubber septum in the lid, followed by gas chromatographic analysis. Lids were removed after sampling, allowing the soils to dry during the incubation period. On day 14, all soils were again wet up, this time to 100% water holding capacity. For the next 10 days, chambers were sampled for gaseous fluxes at the same time intervals as before (i.e. days 1, 2, 4 and 7 after water application). All soils were soil cored at the conclusion of the trial on day 25 and analysed for water content by oven drying at 105 °C, and mineral N by extraction with 1M KCl solution and subsequent colorimetric analysis using a flow injection analyser.

Table 1. Soil properties of the sediment samples collected for the incubation study.

Location	Farm**	Site*	%C	%N	C/N	DOC (mg/kg)	Nitrate (mg N/kg)	Ammonium (mg N/kg)	Water holding capacity (g/g)
Narrabri	An	HD	0.48	0.06	8.6	17	21	1	0.50
Narrabri	An	TD	1.07	0.12	8.9	46	65	7	0.59
Warren	Aw	HD	0.74	0.09	8.6	16	21	1	0.35
Warren	Aw	TD	1.19	0.11	10.6	67	47	3	0.40
Burren Junction	Bw	HD	0.55	0.07	8.2	32	43	2	0.49
Burren Junction	Bw	TD	0.81	0.10	8.2	82	136	2	0.50
Emerald	Em	HD	0.69	0.07	10.3	18	15	1	0.30
Emerald	Em	TD	0.74	0.07	10.1	52	19	2	0.35
Narrabri	Ff	HD	0.65	0.08	8.1	24	38	1	0.46
Narrabri	Ff	TD	0.95	0.12	8.1	69	37	2	0.50
Wee Waa	Gl	HD	0.70	0.08	8.8	9	58	1	0.45
Wee Waa	Gl	TD	1.08	0.13	8.5	105	22	14	0.46
Gunnedah	Gu	HD	1.26	0.12	10.8	25	29	3	0.44
Gunnedah	Gu	TD	1.25	0.12	10.6	63	101	2	0.53
Narromine	Nh	HD	0.78	0.10	7.8	43	53	3	0.37
Narromine	Nh	TD	0.98	0.14	7.3	65	64	96	0.41
Moree	Rb	HD	0.74	0.07	9.8	15	48	2	0.38
Moree	Rb	TD	1.11	0.12	9.4	86	141	4	0.43
Narrabri	Wn	HD	0.75	0.09	8.1	26	41	2	0.34
Narrabri	Wn	TD	1.10	0.11	9.8	62	11	3	0.44

*HD = head ditch; TD = tail drain; **See Farm locations below for abbreviation key

Treatments

Farm locations (10)	Narromine (Nh), Narrabri (An, Ff, Wn), Warren (Aw), Burren Junction (Bw), Wee Waa (Gl), Moree (Rb), Emerald (Em)
Location (2)	Head ditch (HD), tail drain (TD)
Irrigation water (2)	Water only, water-run urea (30 kg N/ha applied to head ditch soils, 5 kg N/ha applied to tail drain samples). All samples also had 10 mg C/L applied as glucose dissolved in the applied solutions.

Results

Nitrous oxide emissions as influenced by irrigation and water-run application

Daily fluxes (Figure 1) were combined to give cumulative totals of N_2O emitted for each sample during the study (Table 2). Statistical analysis of the whole dataset together showed significant differences (P<0.05) according to farm, sample location, solution used, and all interactions between these factors, except for the farm × location × solution interaction.

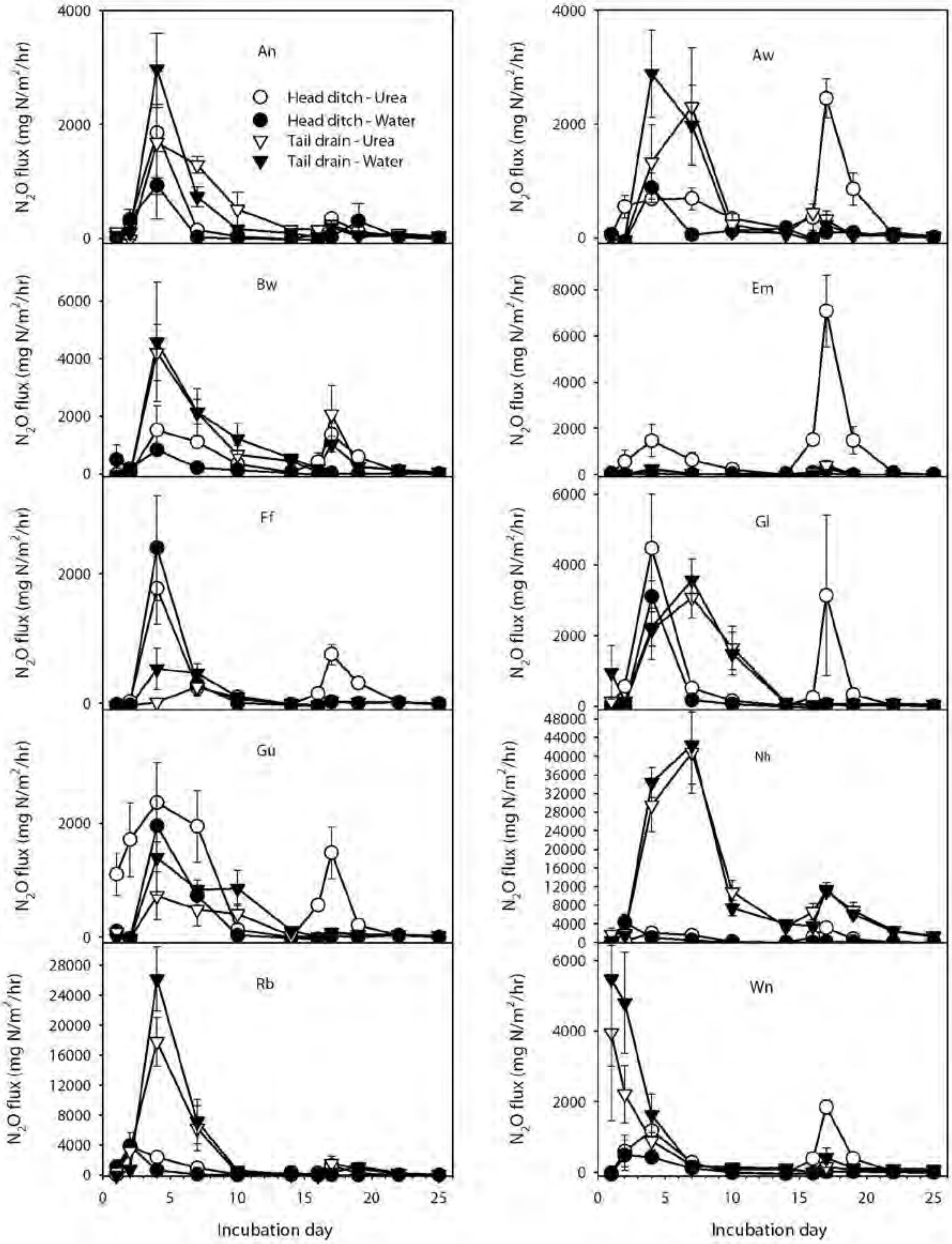

Figure 1. Daily mean nitrous oxide flux for head ditch and tail drain samples of 10 commercial paddocks during incubation with either added water or dissolved urea solution. Each point is a mean of four replicate chambers ± standard error. Note different scales used for each paddock.

In general, the adding urea solution increased fluxes in head ditch samples by between 111–2578% (median increase = 250%), while adding a less concentrated urea solution to tail drain samples had no overall effect. Separate statistical tests on each sample showed that the solution used (water or water-run urea) mostly affected N_2O loss from samples with low initial mineral N concentrations. In all but one case (Ff-tail), there was significantly more N_2O emitted from the treatment with water-run urea solution added compared with water added. It can be seen from Figure 1 that most of the difference occurred during the second simulated irrigation event, as fluxes during the first event were more similar between water and urea solution treatments.

Table 2. Cumulative nitrous oxide (mg N_2O-N/m^2) emitted during incubation according to farm, sample location (head ditch, tail drain), and solution (water, urea). Significant ($P<0.05$) solution effects are indicated by different letters for each pair.

Farm	Head ditch		Tail drain	
	Urea	Water	Urea	Water
An	126	66	250	230
Aw	261[b]	79[a]	287	312
Bw	271	85	522	572
Em	464[b]	18[a]	24[b]	7[a]
Ff	147	132	22[a]	63[b]
Gl	383[b]	167[a]	472	518
Gu	405[b]	150[a]	110	207
Nh	386[b]	189[a]	6715	6635
Rb	339	188	1516	1925
Wn	168[b]	34[a]	232	386

Conclusions

Tail drain samples tended to release more nitrous oxide compared with head ditch samples, with fluxes linked to initial mineral-N concentrations of soil/sediments before the irrigation or water-run urea additions. These non-cropped areas within the farm might be the highest source of N_2O emission per unit area of the paddock as they tend to retain high levels of moisture and nutrients in the soil, especially in the tail drains.

The results suggest that emissions occurring in uncropped head ditch and tail drain soils are mainly influenced by interactions between irrigation and fertiliser management practices, and baseline nitrogen concentrations. In future research, the quantum of these emissions needs to be compared simultaneously with N_2O emissions from cropped areas under field conditions.

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Optimum nitrogen fertiliser rates maintain yields and minimise nitrous oxide emissions

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Key findings

- Fertilising above the optimum plant nitrogen (N) demand level reduced N-use efficiency and increased environmental impact.
- Despite receiving 8–9 irrigations as well as several intense rainfall events in a season, there were typically only 3–4 significant nitrous oxide (N_2O) flux periods during the season, with most occurring early in the season, i.e. irrigations 1 and 2.
- Other significant N_2O emissions events occurred mostly in response to adding in-crop N fertiliser followed by irrigation and/or intense rainfall.
- Initially, higher N_2O emissions came from the beds where N fertiliser had been applied pre-sowing. Later in the season, emissions often peaked in the non-irrigated furrows after rainfall and irrigation events, particularly after additional N was added in the irrigation water.
- Farmers' N rates were at least 25% higher than necessary to achieve the same lint yield in 2014–15, i.e. 50–100 kg N/ha. Less N fertiliser could have produced the same amount of cotton.
- Increasing N rates increased total N_2O emissions, especially in prolonged wet conditions.

Introduction

Recent cotton grower survey results found that 93–370 kg/ha of N fertiliser is applied annually to irrigated cotton, but much of this was used inefficiently, with only 13% of growers achieving an optimum N-use efficiency (NUE) of 12.5–16 kg lint/kg N (Roth Rural 2013). Excess or unused fertiliser N can be lost from the system via several potential pathways, but denitrification is the major avenue of N loss in the medium–heavy clay vertosols of the eastern Australian cotton industry. In addition to gross N loss (as N_2 gas), denitrification also results in N_2O emissions, a greenhouse gas with a global warming potential 298-times greater than that of carbon dioxide (CO_2), and a major ozone-depleting gas. Previous research has shown that up to 3.15% of applied N in irrigated cotton systems can be lost as N_2O (Grace et al. 2016) with losses increasing exponentially beyond 250 kg N/ha applied. Therefore, N_2O emissions from irrigated cotton systems might be substantially mitigated by judicious N fertiliser management to improve nitrogen use efficiency (NUE).

Cotton growers currently use a range of N fertiliser products, product placement strategies (differing in time of application, depth of application and location in the soil), and irrigation practices, resulting in an unknown and largely undocumented range of potential N_2O loss scenarios. This project aimed to test some of the commercial practices used in irrigated cotton growing. In the 2014–15 summer cropping season, three experiments were conducted at commercial farms located near Emerald (Qld), Moree (NSW), and Gunnedah (NSW). At each farm, a replicated randomised experiment incorporated three N-fertiliser rate treatments, including the farmer's chosen rate, a 25% lower rate and a 25% higher rate. Nitrous oxide emissions were monitored throughout the growing season in each plot.

Site details

Trial 1. Emerald

Location	'Wills Road', Emerald
Co-operator	Cam Geddes
Soil type and nutrition	Brown vertosol (clay–loam texture) with 35% clay, 53% sand, 11% silt (0–30 cm).
Rainfall and irrigation	There was 431 mm of rain during the growing season from sowing to harvest. The crop was irrigated eight times. A total of 5.28 ML/ha was applied.

Sowing date and variety	The Emerald site was sown with Sicot 75RRF on 5 September 2014
Harvest (picking) date	Cotton picked with a commercial 6-row picker on 18 February 2015.

Trial 2. Moree

Location	'Red Mill', Moree
Co-operator	Ray Fox
Soil type and nutrition	Black vertosols (medium clay) with 50% clay, 27% sand and 23% silt (0–30 cm).
Rainfall and irrigation	At Moree, there was 373 mm of rain in the growing season. The crop was irrigated 11 times, including one pre-plant irrigation, with a total of 7.5 ML/ha applied.
Sowing dates and varieties	The Moree site was sown with Sicot 74BRF on 24 October 2014.
Harvest date	Cotton picked with a commercial 6-row picker on 25 April 2015.

Trial 3. Gunnedah

Location	'Ruvigne', Gunnedah
Co-operator	Rod Smith
Soil type and nutrition	Black vertosols (medium clay) with 54% clay, 10% sand, 36% silt (0–30 cm).
Rainfall and irrigation	The Gunnedah site had 431 mm rainfall and was irrigated seven times with a total of 7.0 ML/ha.
Sowing dates and varieties	The Gunnedah site was sown with Sicot 74BRF on 8 October 2014.
Harvest date	Cotton picked with a commercial 6-row picker on 8 May 2015.

Trial design (all trials)

The experimental design was a randomised complete block with three treatments and three replicates.

Treatments

At each trial, there were three total rates of N fertiliser applied during the season, including the farmer's chosen rate, a 25% lower rate and a 25% higher rate (Table 1). The fertiliser products, application method and application timing varied according to each co-operating farmer's practice. Each plot was 8–12 rows wide x paddock length, depending on the width of the fertiliser machinery at each farm.

Table 1. N rate treatments used at the three on-farm trial sites in 2014–15.

Site	N applied pre-sowing (kg N/ha)	N applied in-crop (kg N/ha)	Total N applied (kg N/ha)
Emerald	160(i-u)	0	160
	160(i-u)	60(s-uan)	220
	160(i-u)	120(s-uan)	280
Moree	150(aa)	58(w-u) + 62(w-u) + 60(w-u)	330
	150(aa)	58(w-u) + 62(w-u) + 100(s-uan) + 60(w-u)	430
	150(aa)	58(w-u) + 62(w-u) + 200(s-uan) + 60(w-u)	530
Gunnedah	80(aa)	40(b-u) + 40(w-u)	160
	130(aa)	40(b-u) + 40(w-u)	210
	180(aa)	40(b-u) + 40(w-u)	260

i-u = incorporated urea
aa = anhydrous ammonia
s-uan = sprayed urea ammonium nitrate
w-u = water-run urea
b-u = broadcast urea

Nitrous oxide measurements

From sowing until harvest, we used four manual chambers per plot to sample emissions of N_2O from the soil. In each plot, one chamber was located in the irrigated furrow, one in the non-irrigated furrow and two on the crop bed. Gas samples were analysed by a laboratory gas chromatograph. Triggers for gas sampling were:

- fertiliser application
- rainfall
- irrigation events.

The sampling protocols called for up to a week of daily field sampling after each trigger event. Other measurements included:

- monthly surface soil mineral N and water content (0–10 cm)
- post harvest soil mineral N to 90 cm depth
- plant biomass and biomass N content
- cotton lint yield and turnout

Results

Trial 1. Emerald

The first irrigation led to a rapid initial loss of N_2O from the hill position and non-irrigated furrow positions, but few emissions came from the irrigated furrows. Rainfall later in September did not increase emissions, suggesting that it was not sufficiently wet to cause denitrification.

There were two more distinct N_2O loss events (late November and mid January) coinciding with high rainfall (>40 mm) soon after irrigation events. The in-crop N was applied to the soil in early November to the 220 kg N/ha and 280 kg N/ha treatments, which explains why the increase in emissions in late November was not found in the non-irrigated furrow for this treatment. Losses from the non-irrigated furrow appeared to be greatest from the lowest N rate treatment, however, the error margins surrounding these treatment means were large, so treatments were not significantly different.

Overall, cumulative total N_2O losses during the season were relatively small for the amount of N applied (Table 2). The calculated emission factors (EFs = emitted N_2O as a proportion of applied N) were well below the current Australian EF for irrigated cotton (0.55%).

Cotton lint yield averaged 10.7 bales/ha across the trial and was not significantly affected by N rate treatment.

Table 2. Cumulative N_2O–N released from the three N rate treatments per hectare and as a percentage of the fertiliser N applied at the three on-farm trial sites in 2014–15.

Site	Total N applied (kg N/ha)	Cumulative N_2O emitted (g N_2O–N/ha)	N_2O emission factor (EF) (% of applied N emitted as N_2O)
Emerald	160	407[ns]	0.25[ns]
	220	372	0.17
	280	487	0.17
Moree	330	2669[a]	0.81[a]
	430	3468[a]	0.81[a]
	530	9282[b]	1.75[b]
Gunnedah	160	745[a]	0.37[ns]
	210	970[ab]	0.39
	260	1134[b]	0.38

Letters after N rate means from a site denote significant treatment differences. NS = no significant difference (P>0.05)

Trial 2. Moree

Nitrous oxide emissions were moderate until late November, when irrigation and intense rainfall triggered an increased rate of loss. However, applying in-season N fertiliser, followed by irrigation and a >50 mm rainfall event in early January, combined to greatly increase the rate of N_2O emissions. This was especially true from the non-irrigated furrow where UAN was applied in the 430 kg N/ha and 530 kg N/ha treatments. Emissions from the non-irrigated furrow of the 530 kg N/ha treatment continued at a high rate until February, resulting in very high N_2O loss from this position of this treatment. The calculated EFs for the Moree site (Table 2) exceeded the Australian default EF for irrigated cotton in all three N rate treatments, with the top N rate showing that when N applied is greatly in excess of that required, emission losses increase exponentially. By the end of the season there was only 23 kg N/ha remaining in the soil to 90 cm depth with no effect of either N fertiliser rate or sample location on soil mineral N.

All three N rate treatments yielded an average of 13.2 bales/ha. Therefore, applying an additional 200 kg N/ha above the lowest N rate did not benefit productivity.

Trial 3. Gunnedah

The scale of N_2O losses was greater at Gunnedah than Emerald, but less than Moree (Table 2). At the Gunnedah site, the N_2O losses tended to be in proportion to the differences in N rates, as the N-rate differences were established in the pre-plant N application, rather than through differences in in-crop application as was the case at the other two sites.

The greatest rate of N_2O loss occurred from the hill position where the fertiliser had been pre-applied. The next highest flux occurred after the next irrigation in early November. Despite heavy December rainfall, the N_2O losses were small until after the in-crop N application in mid January. There were few losses after January 2015 despite further irrigation and rainfall events.

More N_2O was emitted from the non-irrigated furrows than the irrigated furrows. By the end of the season there was little mineral N remaining in the surface soil at any of the chamber locations, and only 30–90 cm depth, averaged across the site. The calculated EFs were below the Australian default EF figure for irrigated cotton (0.55%) and showed no variation with N-rate.

Lint yield across the trial averaged 13.0 bales/ha with no significant treatment effect of N fertiliser rate.

Conclusions

The intensive sampling of gas emissions from the three N-rate trials showed that, despite receiving 8–11 irrigations as well as several intense rainfall events in a season, there were typically only 3–4 significant N_2O flux periods during the season – a finding we used to better target sampling in following years. In 2014–15, gas sampling began just after sowing with the first noticeable fluxes occurring in conjunction with the first irrigation after planting. In later years, gas sampling began after the pre-plant N application to capture N_2O losses occurring after pre-plant rainfall events.

At Moree and Gunnedah, the second irrigation also led to increased N_2O emissions, which had effectively ceased as the soil dried down after the initial irrigation. Further significant emission events occurred in response to adding in-crop N fertiliser followed by irrigation and/or intense rainfall. This was especially the case at Moree, where the spray application of UAN onto the soil surface of the non-irrigated furrows, followed by irrigation and 60 mm rain, led to extremely high N_2O losses in the 430 kg N/ha and 530 kg N/ha treatments. These losses continued at a high rate for nearly two months and resulted in a proportional N_2O loss well above the default Australian EF of 0.55%.

Previous research elsewhere has concluded that N fertiliser applied at rates in excess of crop requirements will lead to exponential increases in N_2O emitted (and therefore an increase in EF). However, we only saw this occurring at Moree when long period of wet soil conditions followed the in-crop N. Fertiliser N rates were clearly in excess of crop requirements at all three trial sites as there was no lint yield response to increasing N rate. Therefore, the farmer's chosen N rate at all sites was at least 25% higher than necessary to achieve the same lint yield in that year of cropping, i.e. between 50 kg N/ha and 100 kg N/ha less N fertiliser could have been used to grow the same amount of cotton at those farms. At the Moree and Gunnedah sites, using the lower rate would have reduced the farm's nitrous oxide emissions by 24–26%.

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Acknowledgements

This experiment was part of the project *Determining optimum nitrogen strategies for abatement of emissions for different irrigated cotton systems* (AOTG14013; 2013–17), with joint investment by NSW DPI and DAWR, and administered by CRDC.

Thanks to Cam Geddes, Ray Fox and Rod Smith for providing the experimental sites and for applying the N rate treatments in their fields. We also thank Amanda Noone and Renee Anderson (Emerald), Megan Adams and Alice Devlin (Moree), Wayne McPherson, Mandy Holland, Tara Burns, Tim Grant and Jon Baird (Gunnedah) for soil and gas sample collection. Thanks to Nicole Morris and Brad Keen for soil and plant N analyses at the ISO9001–accredited laboratory at Wollongbar Agricultural Institute, NSW DPI.

Does split-nitrogen application reduce nitrous oxide emissions from irrigated cotton compared with all nitrogen applied pre-season?

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Key findings

- Nitrous oxide (N_2O) emissions at the Gunnedah site were approximately three times higher than at the Emerald site, probably because of the heavier clay soil at Gunnedah.
- High and highly variable N_2O emissions occurred at both sites during the week following the first irrigation event after the pre-planting nitrogen (N) application. There was no significant effect from the amount of N applied at pre-planting on these first emissions, nor overall at Gunnedah. At Emerald, overall N_2O losses were greater from the split N treatment.
- N_2O emissions were low–negligible following the subsequent 4–5 irrigation events, except where N was water-run, which caused small and temporary increases in N_2O.
- The greatest N_2O emission came from the soil above the pre-plant N fertiliser bands. More was emitted from the non-irrigated side of the plant bed, even when both sides of the bed had been fertilised (Emerald).
- Cotton lint yield was not affected by N timing treatment, however, plant biomass was smaller and more N-concentrated from the split N treatment at Gunnedah.
- The 2015–16 weather conditions did not favour either N-timing treatment agronomically or environmentally, but different rainfall patterns in other years may be more influential.

Introduction

Nitrogen fertiliser is a major input required for high-yielding irrigated cotton cropping systems, but its use has environmental consequences in the form of increased soil N_2O emissions. Farmers across the northern Australian irrigated cotton region use a range of N fertiliser application products, application placement and timing strategies to produce high-yielding crops, but the effects of the different strategies on N_2O emissions are not well known. While the in-season N uptake into the cotton plant follows an established pattern of very slow accumulation during the initial two months followed by a period of rapid N uptake, farmers often apply all of the crop's N fertiliser into the soil several weeks to months before planting occurs. In contrast, other farmers apply part of the season's N requirement pre-planting, with the remainder applied in-crop, either by side-dressing, broadcasting ahead of irrigation, or dissolved in the irrigation water used in one or more post-establishment irrigation events.

This paper describes experiments at two locations (Emerald and Gunnedah) that aimed to assess the effect that N fertiliser timing (all applied pre-planting vs pre-planting + in-crop) had on soil N_2O emissions and cotton production.

Site details

Experiment 1. Emerald

Location	'Wills Road', Emerald
Co-operator	Cam Geddes
Soil type	Brown vertosol (clay–loam) with 35% clay, 53% sand, and 11% silt at 0–30 cm soil depth.
Rainfall and irrigation	There was 39 mm of rain during the 75 day pre-planting period between N application and planting, then another 401 mm rainfall during the cropping season from planting to picking. Of this, 335 mm fell in the 45 days before picking. The crop was irrigated nine times, including a pre-planting irrigation on 7 July 2015.

Trial design	Randomised complete block design with three replications of three treatments – only two treatments are discussed in this paper (T1 = split N; T3 = all N applied pre-planting). Each plot was 12 rows, planted on 1 m row spacing, and 1500 m long (paddock length).
Sowing date and variety	10 September 2015. Sicot 75RRF
Harvest (picking) date	3 February 2016

Treatments

Treatment 1 (T1, split N) = 180 kg N/ha pre-planting N applied on 27 June 2015 as urea drilled into both sides of every hill, then three in-crop applications of 20 kg N/ha as UAN applied in the 4th, 5th and 6th irrigations.

Treatment 3 (T3, all pre-planting) = 240 kg N/ha pre-planting N applied on 27 June 2015 as urea drilled into both sides of every hill.

Site details

Trial 2. Gunnedah

Location	'Ruvigne', Gunnedah
Co-operator	Rod Smith
Soil type and nutrition	Black vertosol (medium clay) with 65% clay, 9% sand and 26% silt at a soil depth of 0–30 cm.
Rainfall and irrigation	There was no rainfall during the 15 day pre-planting period between N application and planting, but there was 405 mm rainfall during the cropping season. The crop was irrigated eight times with approximately 7 ML/ha applied in total.
Trial design	Randomised complete block design with three replications of three treatments – only two treatments are discussed in this paper (T1 = split N; T3 = all N applied pre-planting). Each plot was eight rows, planted on 1 m row spacing, and 560 m long (paddock length).
Sowing date and variety	1 October 2015. Sicot 74BRF
Harvest (picking) date	8 May 2016

Treatments

Treatment 1 (T1, split N) = 100 kg N/ha as anhydrous ammonia injected pre-planting on 16 September 2015 into the hill on the non-irrigated side, then two in-crop applications of 40 kg N/ha applied as water-run urea in the second and third irrigations.

Treatment 3 (T3, all pre-planting) = 180 kg N/ha as anhydrous ammonia injected pre-planting on 16 September 2015 into the hill on the non-irrigated side.

Measurements

Nitrous oxide measurements (both sites)

Nitrous oxide emissions were measured during 5–6 separate 7-day campaigns with samples collected 1, 2, 4, and 7 days after early–mid season irrigation events including pre-planting irrigation.

Results from the 2014–15 season indicated negligible N_2O emissions from mid–late season irrigations. Each plot had four chambers: two in the furrows and two on the plant beds. The concentrations of N_2O in air sampled at 0 and 60 minutes after sealing the chamber with a gas-tight lid were determined using a laboratory gas chromatograph. Hourly emission rates were calculated from the increase in N_2O concentration with time over the time of chamber closure, then extrapolated to a daily flux result. Cumulative losses across the 5–6 sampling events were determined by linear extrapolation between sampling days. Days outside the sampling events were not included in the cumulative totals.

Other measurements

Treatment effects on cotton crop production were evaluated by 3 × 1 m length biomass cuts per plot peak biomass, and machine harvesting by commercial cotton picker in the middle six rows of each plot.

Results

Emerald site

The highest daily emissions of the whole season, and most variable, were measured two days after the initial pre-planting irrigation in both treatments. These high fluxes occurred in the non-irrigated hill position (T1 and T3), and in the non-irrigated furrow position (T1 only). The emissions after subsequent irrigation events were smaller and tended to be higher in the non-irrigated hill and furrow positions. Emissions from the irrigated furrows in all treatments were low across the whole season.

The cumulative emission of N_2O during the six sampling events was significantly greater from T1 than from T3 when all sampling events and chamber location results were combined into a total cumulative N_2O loss (122 vs 88 g N_2O-N/ha) (Figure 1). N_2O loss from a 7-day sampling event was greater from T1 during irrigations 4, 5 and 6 when water-run UAN was applied. Sampling position significantly affected net N_2O loss, especially after the first irrigation, with the greatest loss from the non-irrigated side of the hill, then the non-irrigated furrow, then the irrigated hill and irrigated furrow positions.

Results from the hand-cut biomass assessments showed no treatment differences in plant population, boll number, dry matter or dry matter N content. Likewise, there was no N treatment effect on lint yield or seed N content. Overall, the lint yield was down on expectations due to heavy rainfall in the last weeks before picking, with yields averaging 11.0 bales/ha across these two treatments.

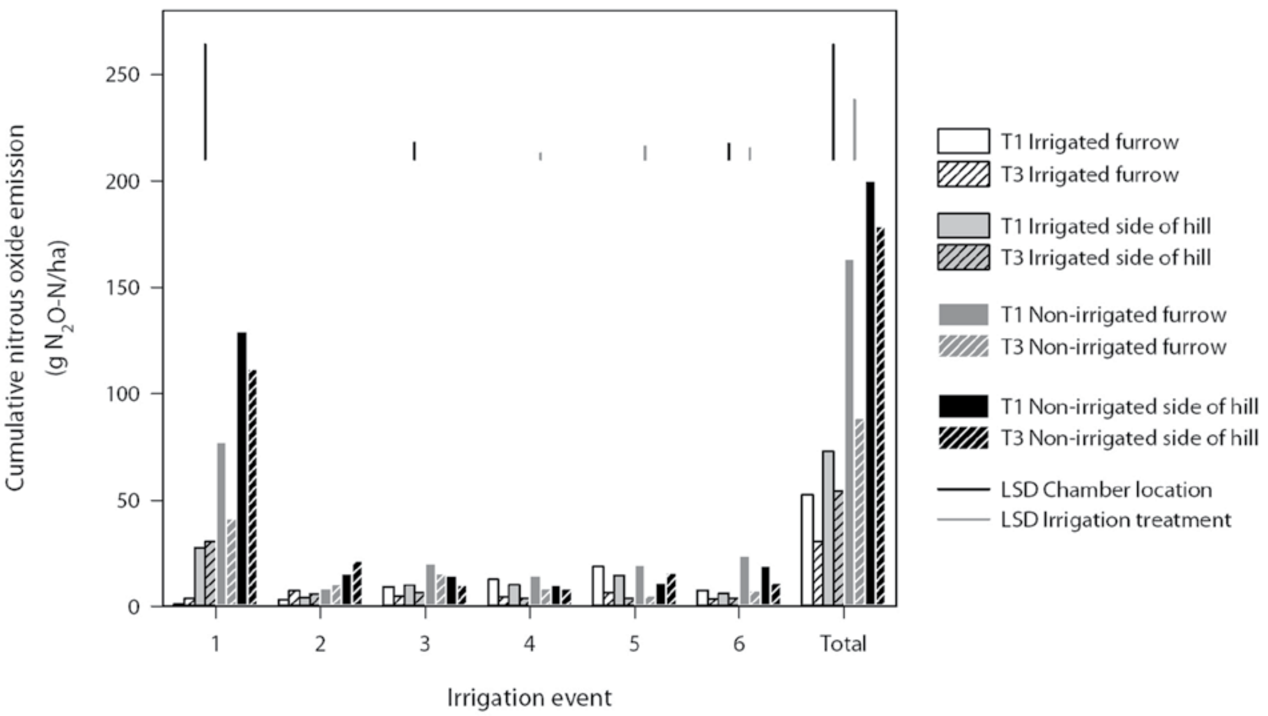

Figure 1. Cumulative nitrous oxide emitted during each 7-day sampling event at the Emerald site as influenced by N treatment and sampling chamber location.

Nutrition and soils

Gunnedah site

High and highly variable N_2O emissions occurred following the first irrigation event, with one chamber in T3 recording a flux of 768 g N_2O-N/ha/d on the first day after irrigation. The highest fluxes were measured in chambers located above the N fertiliser band, while fluxes from the other positions were much lower and not significantly different (Figure 2). The high fluxes from the fertiliser band location decreased after four days but, unlike the other chamber positions, had not yet reached the baseline emission level even after seven days post-irrigation.

In T1, moderate N_2O emissions occurred in response to the water-run urea applied in irrigations 2 and 3. The highest fluxes in T1 were found in the non-fertilised hill position (on the irrigated side). There were negligible N_2O emissions in response to irrigations 4 and 5 (T1), and to irrigations 2–5 for T3. Cumulative emissions across the five sampling occasions showed no significant difference between the N treatments, but the fertilised band position was clearly the greatest overall source of N_2O emitted.

There was no statistical difference in plant population, boll number, biomass N content, commercially-harvested lint yield (14.2 bales/ha) or lint quality attributable to the N treatments. However, there was a significant treatment effect on the maximum plant biomass (dry matter) produced, with plants in T1 smaller than those in T3. There was also a treatment effect on N concentration of the biomass, with T3 (1.75%) statistically less than T1 (1.99%).

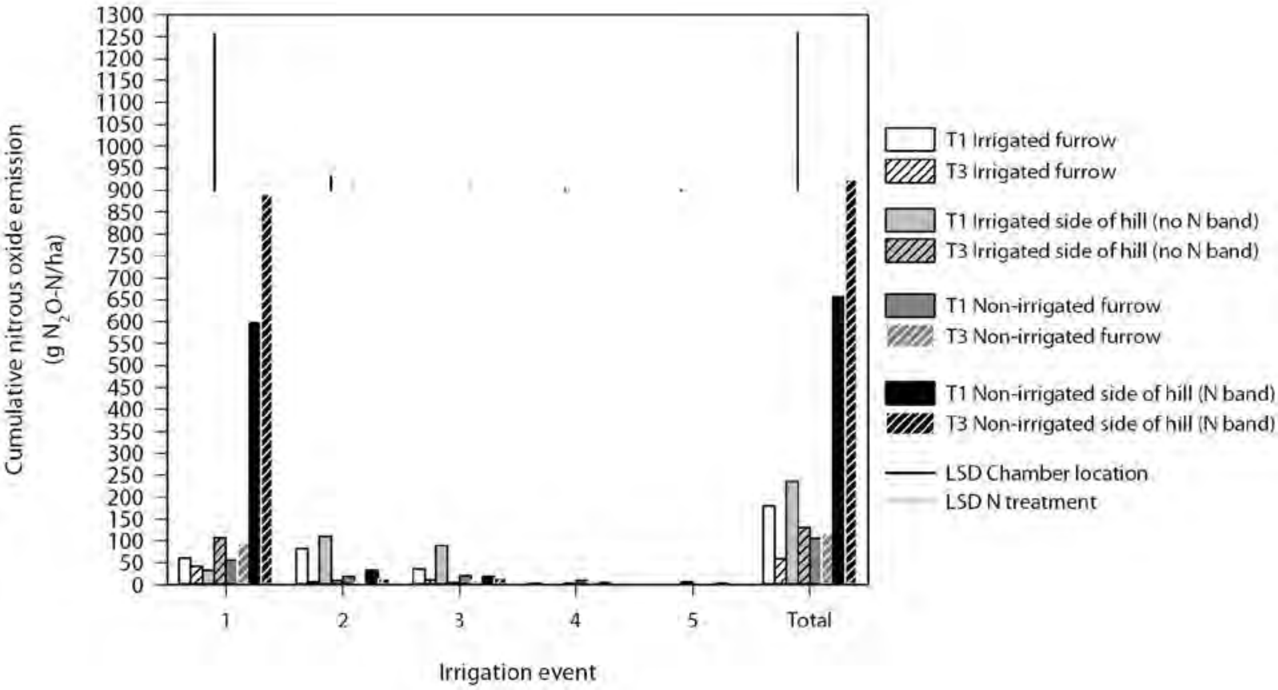

Figure 2. Cumulative nitrous oxide emitted during each 7-day sampling event at the Gunnedah site as influenced by N treatment and sampling chamber location.

Conclusions

Of the five or six week-long sampling campaigns following the early–mid season irrigations, the highest emission losses followed the first irrigation after pre-planting fertiliser had been applied. These high emissions were highly variable at both sites, so there was no statistically significant effect of the rate of pre-planting N applied on the amount of N_2O emitted over the following week. Subsequent irrigation events produced only small–negligible N_2O emissions from T3 where no further N was applied, while emissions in T1 were significantly greater only when N fertiliser was water-run. Total in-crop rainfall was high at both sites, but the majority fell late in the growing season after soil mineral N concentrations were depleted by plant N uptake, so rainfall-induced N_2O losses would have been minimal between irrigation events. At Emerald, total emissions of N_2O summed across the six sampling campaigns, were significantly greater when N applications were split than when applied all at pre-planting, whereas at Gunnedah there was no statistical effect of N application timing.

Nitrous oxide emissions differed hugely depending on sampling position within a plot. At the first irrigation, N_2O losses were highly concentrated from the soil directly above the N fertiliser application band. At Emerald, the N fertiliser was banded on both sides of every plant bed, yet emissions were much greater from the non-irrigated side of the bed than from the irrigated side, which could indicate that nitrate N has concentrated on this side of the plant bed as the irrigation water subbed across to the non-irrigated furrow. This pattern was reversed when water-run N fertiliser was applied, with more N_2O emitted from the irrigated sides of the plant bed at both sites. Initial N_2O losses at Gunnedah were predominantly from above the N banded position on the non-irrigated side of the plant bed. A more detailed 12 chamber sampling exercise (data not shown) found our choice of four chamber positions gave a satisfactory average of the whole plot when combined.

At Gunnedah, the N timing treatments caused significant differences in plant growth and N uptake, but at neither site did N treatment affect cotton lint yield, possibly due to the more-than-adequate N rates used.

From these experiments in this particular season, there was no clear choice of best N timing strategy for greater environmental or agronomic benefit. Years with wetter pre-sowing and early season conditions, such as 2016–17 would likely favour treatment T1 as there is less soil N at risk of loss in the period of up to five months before rapid plant N uptake by the crop.

Acknowledgements

These experiments were part of the project *Determining optimum nitrogen strategies for abatement of emissions for different irrigated cotton systems* (AOTG14013; 2013–17), with joint investment by NSW DPI and DAWR, and administered by CRDC. Thanks to Cam Geddes and Rod Smith for providing the experimental sites and for applying the N fertiliser treatments into the required plots, and to Amanda Noone and Wayne McPherson for field work at Emerald and Gunnedah, respectively. All soil and plant N analyses were carried out by Clarence Mercer at the ISO9001-accredited laboratory at Tamworth Agricultural Institute, NSW DPI.

The impact of irrigation intensity on nitrous oxide emissions and lint yield of irrigated cotton at Emerald, Qld in 2015–16

Graeme Schwenke and Annabelle McPherson
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Key findings

- Increasing siphon pipe diameter used for flood irrigation, from 42 mm to 63 mm halved irrigation time, reduced the amount of water applied per irrigation, and increased cotton lint yield and lint quality.
- The longer irrigation time increased soil water content for up to a week post irrigation, and likely led to waterlogging effects on cotton plant growth.
- The maximum daily nitrous oxide (N_2O) emissions occurred in response to the first irrigation event after pre-plant nitrogen (N) application and continued for more than a week after irrigation.
- The highest N_2O emissions in each plot came from the non-irrigated side of the plant bed where surface soil nitrate concentrations were also highest – despite pre-plant N fertiliser being applied evenly to both sides of the plant bed.
- Postharvest, excess soil nitrate was found to depth in the non-irrigated side of the plant bed, indicating that nitrate moved both sideways and downwards during the season.

Introduction

Soil-based emissions of nitrous oxide (N_2O) are produced during the microbial processes of nitrification (ammonium → nitrate) and denitrification (nitrate → di-nitrogen gas). Nitrification is an aerobic process with activity peaking when approximately 50% of the soil's pore space is filled with water. Denitrification is an anaerobic process, which occurs when a soil has been waterlogged for an extended period. Nitrous oxide production from the denitrification process peaks at approximately 70% of water-filled pore space, with di-nitrogen gas the main denitrification product at higher soil moisture levels. Denitrification also requires a high initial soil nitrate concentration (e.g. soon after soils have been fertilised) and a source of readily available (labile) carbon to support microbial activity.

Cotton irrigation practices that lead to prolonged high soil moisture conditions can, therefore, increase denitrification losses of soil mineral N and increase emissions of environmentally damaging N_2O into the atmosphere.

This experiment aimed to assess the impact of two alternative cotton irrigation strategies on soil mineral N: crop production and N_2O emissions. Using different diameter siphons to apply irrigation water should lead to differences in the rates of water application and therefore the length of time required to fully wet-up the crop beds. The change in watering strategy also included a comparison of pre-plant watering followed by a smaller post-plant irrigation versus a dry-planting followed by a larger post-plant irrigation.

Site details

Location	'Wills Road' (Emerald, Qld)
Co-operator	Cam Geddes
Soil type	The soil is a Brown vertosol with a clay–loam texture (0–30 cm; 35% clay, 53% sand, 11% silt).
Rainfall and irrigation	A total of 39 mm of rain fell during the 75-day pre-plant period between N application and sowing. There was another 401 mm rainfall during the cropping season from sowing to harvest. Of this, 335 mm fell in the last 45 days before harvest. The site was irrigated 8–9 times in total.

Trial design

Randomised complete block design with three replications of three treatments. Only two of the three treatments are discussed in this paper as the third treatment did not involve irrigation. Irrigation water was applied through either 63 mm diameter siphons for a maximum of 12 hours (T1), or through 42 mm diameter siphons for a maximum of 24 hours (T2). T1 had a pre-plant irrigation of 1.5 ML/ha soon after the pre-plant N was applied, and a post-plant irrigation of 1.0 ML/ha. T2 had no pre-plant irrigation, but had 2.5 ML/ha applied post-planting. Approximately 0.55 ML/ha (T1) and 0.72 ML/ha (T2) were applied in each subsequent irrigation event.

Both irrigation treatments had the same split N applications throughout the season, with 180 kg N/ha pre-plant N as urea drilled into both sides of every hill, then three in-crop applications of 20 kg N/ha as UAN applied in the 4th, 5th and 6th irrigations. The pre-plant N fertiliser was applied on 27 June 2015 and was followed by a pre-plant irrigation on 7 July 2015 (T1 only). Each plot was 12 rows (× 1 m) wide and 1500 m long (paddock length).

Sowing

The site was sown with Sicot 75RRF on 10 September 2015

Harvesting

The trial was harvested with a commercial six-row picker on 23 February 2016. All cotton from each plot was baled separately, then weighed, ginned and quality-tested at a commercial gin.

Nitrous oxide measurements

Nitrous oxide emissions were measured during five separate seven-day periods with samples collected 1, 2, 4, and 7 days after early–mid season irrigation events, including pre-plant irrigation. Results from the 2014–15 season indicated negligible N_2O emissions from mid–late season irrigations, so late-season irrigations were not monitored in this 2015–16 study.

Each plot had four chambers: two in the furrows, two on the plant beds. The concentrations of N_2O in air sampled at 0 minutes and 60 minutes after sealing the chamber with a gas-tight lid were determined using a laboratory gas chromatograph. Hourly emission rates were calculated from the increase in N_2O concentration with time over the time of chamber closure, then extrapolated to a daily flux result. Linear extrapolation between sampling days was used to determine cumulative losses within each of the sampling periods. Days outside the sampling events were not included in the cumulative totals.

Soil N and mineral N measurements

Soil moisture content was measured at each gas sampling occasion using a hand-held theta-probe previously calibrated using volumetric soil moisture measurements from the site. Soil mineral N (ammonium and nitrate) was measured in surface soil (0–10 cm) samples collected near each N_2O chamber location at approximately monthly intervals during the experiment. After harvest, mineral N was also measured in segmented soil cores taken to 90 cm depth (0–30, 30–60, 60–90 cm) at each chamber location. At each sampling time, soil was extracted with 1M KCl and analysed colorimetrically using a flow-injection analyser.

Plant measurements

Treatment effects on cotton crop production were evaluated for each plot from biomass cuts collected at peak biomass (3 × 1 m length), hand-picked lint samples at harvest (3 × 1 m length), and machine harvesting by a commercial cotton picker from the middle six rows of each plot over the entire plot length. Nitrogen concentration in dried and finely-ground plant and seed samples was measured using a combustion analyser.

Results

The cumulative N_2O emitted during the seven-day measurement period following each of the first six irrigation events is shown in Figure 1. Irrigation treatment led to a significant difference in N_2O loss in four of the six irrigation events monitored for gas emissions. The highest and most variable daily emissions of the whole season occurred in response to the first irrigation applied to both treatments. For T1, this was the pre-plant irrigation in July 2015 following the pre-plant N fertiliser applied in late June (irrigation event 1). For T2, this was not until the post-planting irrigation in September 2015 (irrigation event 2). Additional bi-weekly measurements made using a semi-automated sampling system (data not shown) showed that emissions following the initial irrigation continued for more than the seven-day manual chamber measurement period for T1. No semi-auto sampling chambers were used in T2.

Following irrigation 1 (pre-plant; 8/7/15), emissions from T1 were much greater than from the non-irrigated T2 in all positions except the irrigated furrow (Figure 1). Conversely, results from the second irrigation (12/9/15) showed more N_2O lost from T2 than T1 in all but the irrigated furrow once again. T2 emissions also exceeded T1 following the third irrigation (21/10/15), but the reverse occurred for the fifth irrigation (21/11/15). There was no significant irrigation treatment effect on total N_2O emitted when summed over the six irrigation events (Figure 1).

Sampling position (chamber location) had a strong influence on N_2O emissions, with the greatest loss from the non-irrigated side of hill, then the non-irrigated furrow, then the irrigated side of hill and finally, irrigated furrow positions.

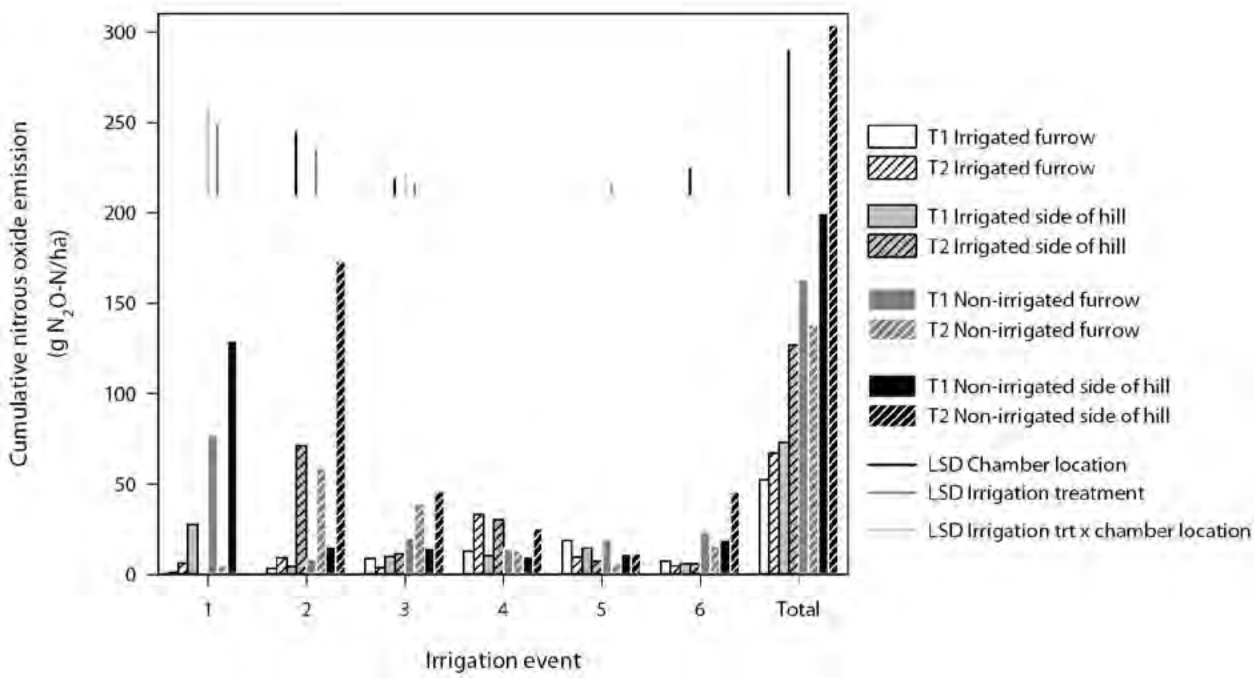

Figure 1. Cumulative nitrous oxide emissions as influenced by irrigation intensity treatment – Emerald, Qld 2015–16. Note: T2 was not irrigated at irrigation event 1. In this graph l.s.d.$_{0.05}$ are shown where irrigation treatment or chamber position means were significantly different (P<0.05).

Following the post-plant irrigation (irrigation 2), the surface soil in T2 after subsequent irrigations was significantly wetter than T1 in all measurement positions. In most cases, the differences lasted for the week-long duration of post-irrigation gas measurements (data not shown).

Soil nitrate concentrations (0–10 cm) showed distinct treatment-induced patterns of nitrate accumulation in the topsoil, mostly in the two hill positions (Figure 2). After the pre-plant irrigation, soil nitrate accumulated in T1, particularly in the non-irrigated hill position. During the pre-plant period, the soil in T2 remained very dry, so there was little nitrification leading to the accumulation of nitrate. After the third irrigation (21/10/15), nitrate concentrations were high in the non-irrigated hill position and remained high until the end of the year.

The water-run N applications appeared to maintain or increase soil nitrate at the levels found before water-run began, particularly in the non-irrigated side of the hill position. T1 showed a large initial accumulation of nitrate N in the irrigated side of the hill position after the second irrigation (12/9/15), but after this time, nitrate in this position was generally low. This change could indicate nitrate moving laterally from the irrigated hill position across to the non-irrigated hill position during subsequent irrigations. There were still significant concentrations of nitrate N in the non-irrigated hill positions of T1 and T2 at the latest soil sampling in January 2016.

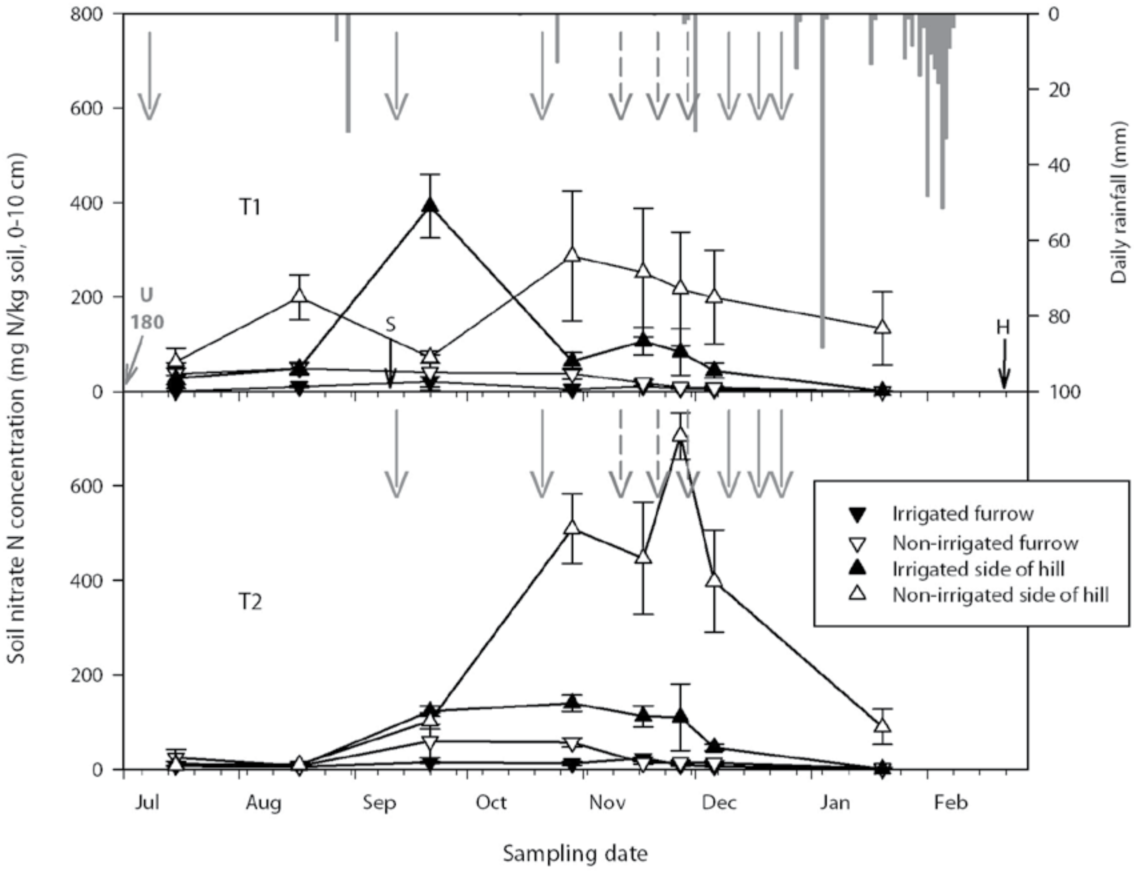

Figure 2. Soil nitrate N concentration (0–10 cm) at the four chamber positions within each treatment. Daily rainfall is indicated in the top graph, and irrigation event timing is indicated for each treatment by the downward arrows. Solid arrows = water-only irrigations, dashed arrows = water-run UAN, U180 = pre-plant urea, S = sowing, H = harvest.

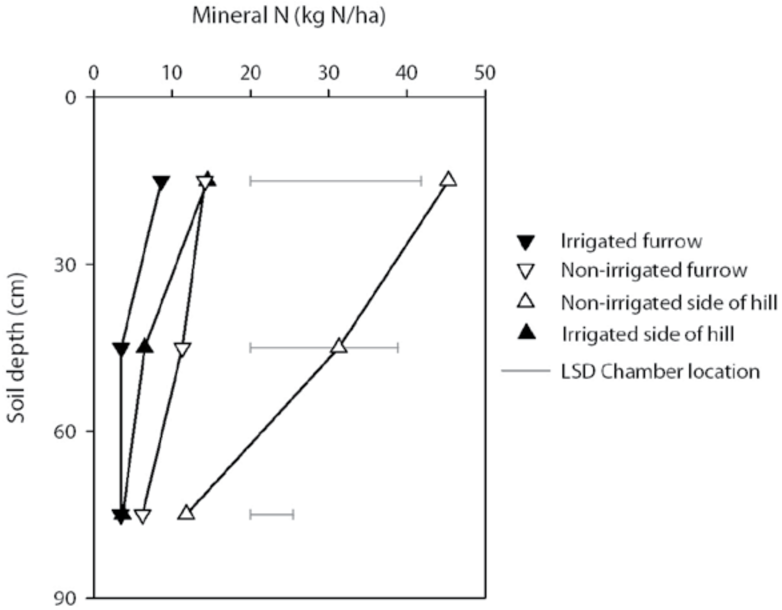

Figure 3. Mineral N (nitrate + ammonium) in the soil to 90 cm depth from all locations used for manual chamber sampling. Data are averaged across all trial treatments as there was no significant treatment difference at any depth.

There was no residual treatment effect on soil mineral N results after harvest. However, there was a significant effect of sampling (chamber) location within the plot on total soil mineral N, with much more N found at all depths in the non-irrigated hill position, regardless of treatment (Figure 3). The variation seen in sample results from this location are high because all three plots in the third replicate (i.e. plots 7, 8 and 9) had very high nitrate results, regardless of N treatment.

Irrigation intensity significantly affected commercially harvested lint yield and quality, with T1 = 11.0 bales/ha and T2 = 10.1 bales/ha (l.s.d. = 0.5 bales/ha). Treatment did not affect lint colour, strength or length, but T1 scored higher than T2 for uniformity (81.8 vs 81.5) and micronaire (4.70 vs 4.57). Micronaire is a measure of the air permeability of compressed cotton fibres and is used to indicate fibre fineness and maturity.

There was no significant effect of the two irrigation treatments on seed N content.

Results of the hand-cut biomass assessment showed no significant treatment differences in plant population, boll numbers, dry matter or dry matter N content.

Conclusions

It is likely that the larger amounts of irrigation water applied to T2 compared with T1, as well as the longer irrigation times, might have led to greater waterlogging in T2, with damage to plant roots possibly affecting lint production. Previous research has shown that waterlogging early in crop growth has a larger influence on cotton yield than later in the season. The effect on yield is typically associated with reductions in final boll number, but we found no significant treatment effect on boll number in the assessments made at maximum biomass production.

In a Google Earth satellite image taken in late November 2015, the T2 plots are distinctly yellowish in colour compared with the dark green colour of T1 plots. This tends to suggest that the plants in these plots were N deficient, although our surface soil sampling found high concentrations of nitrate N in the plant bed at this time. Also, there was no treatment effect on either biomass N uptake or seed N concentration from biomass hand cuts and lint hand picking data. Further, the fact that the first two of the three in-crop N applications were not able to 'green up' the cotton in T2 before this photo was taken suggests that perhaps waterlogging damage rather than N deficiency was the cause of the visible symptoms and reduced lint yield.

Waterlogging or not, all plots in the trial showed higher concentrations of mineral N (as nitrate) in the non-irrigated hill position, and not just at the surface. All three sampling depths to 90 cm were significantly higher in nitrate compared with the irrigated side of the hill or either furrow position, indicating that nitrate N leached both sideways and downwards during the season. Ultimately, this nitrate N was excess to the cotton crop's requirements and will remain in the soil until it is either taken up by a following crop, leached further down as the profile refills with moisture, or denitrified in later waterlogging events.

In a productivity and product quality comparison, the current practice (T1) clearly led to an improvement over the previous practice (T2). While there was no difference in total N_2O emissions caused by the change in irrigation intensity, the change in lint yield means there was an improvement in N_2O emissions intensity per unit product.

Acknowledgements

This experiment was part of the project *Determining optimum nitrogen strategies for abatement of emissions for different irrigated cotton systems* (AOTG14013; 2013–17), with joint investment by NSW DPI and DAWR, and administered by CRDC.

Thanks to Cam Geddes for providing the experimental site and applying the irrigation treatments and to Amanda Noone for field measurements. All soil and plant N analyses were carried out by Clarence Mercer at the ISO9001-accredited laboratory at Tamworth Agricultural Institute, NSW DPI.

Does pre-plant N fertiliser location affect soil mineral N and nitrous oxide emissions from irrigated cotton at Gunnedah?

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Key findings

- Changing the pre-plant N fertiliser from the non-irrigated side of the plant bed to the irrigated side of the plant bed did not affect soil mineral nitrogen (N), plant growth or cotton lint yield.
- The pattern of nitrous oxide (N_2O) emissions after the first irrigation event differed according to N fertiliser placement treatment, but the total amount of N_2O released was the same.
- Pre-plant N fertiliser placement did affect N_2O emitted after the second irrigation (with water-run N), with more lost from the irrigated, non-fertilised side of the hill.
- The cumulative N_2O losses summed over all the measurement events showed no treatment differences resulting from pre-plant N fertiliser location, indicating that there is no agronomic or environmental benefit to changing N fertiliser location.

Introduction

In a typical cotton furrow irrigation system, water is applied to every second furrow. During the irrigation event, water 'subs' sideways through the plant bed from the irrigated furrow and eventually into the non-irrigated furrow. Pre-plant N fertiliser is applied down into one or both sides of the formed plant bed, usually to a depth below that of the furrows.

In this experiment, we compared this conventional practice with an alternative pre-plant N fertiliser placement in relation to the irrigated furrow, to investigate the potential impact on soil mineral N concentrations and consequent N_2O emissions.

Site details

Location	'Ruvigne' Gunnedah
Co-operator	Rod Smith
Soil type	Black vertosol. The soil (0–30 cm) was 65% clay, 9% sand and 26% silt.
Rainfall and irrigation	At Gunnedah, there was no rainfall during the 15-day pre-plant period between N application and sowing, but there was 405 mm of rainfall during the cropping season. The crop was irrigated eight times with approximately 7 ML/ha applied in total.
Trial design	Randomised complete block design with three replications of three treatments. Each plot was eight rows (× 1 m) wide and 560 m long (paddock length).
Sowing date	The site was sown with Sicot 75RRF on 10 September 2015.
Harvest date	The trial was harvested with a commercial six-row picker on 23 February 2016. All cotton from each plot was baled separately, then weighed, ginned and quality-tested at a commercial gin.

Treatments

Three treatments were applied, however, only two of the treatments are discussed in this paper as the third treatment concerned N fertiliser timing, not N placement, and is discussed in a separate paper.

Treatment 1 (T1): a pre-plant application of 100 kg N/ha as anhydrous ammonia was injected into the non-irrigated side of the plant bed.

Treatment 2 (T2): a pre-plant application of 100 kg N/ha anhydrous ammonia was injected into the irrigated side of the plant bed.

The pre-plant N fertiliser was applied on 16 September 2015. Both treatments had in-crop N applications of 30 kg N/ha applied as water-run urea in the second and third irrigations.

Measurements

Soil moisture and mineral nitrogen measurements

Soil moisture content was measured at each gas sampling occasion using a hand-held theta-probe calibrated using volumetric soil moisture measurements at each site. Soil mineral N (ammonium and nitrate) was measured in surface soil (0–10 cm) samples collected near each N_2O chamber location at approximately monthly intervals during the experiment. After harvest, mineral N was also measured in soil cores taken to 90 cm depth (0–30, 30–60, 60–90 cm) at each chamber location. At each sampling time, soil was extracted with 1M KCl and analysed colorimetrically using a flow injection analyser.

Nitrous oxide measurements

Nitrous oxide emissions were measured during five separate seven-day campaigns with samples collected 1, 2, 4, and 7 days after irrigations 1–5, including the pre-plant irrigation (irrigation 1). Measurements done in the previous year showed negligible N_2O emissions from late-season irrigations, so these were not monitored.

Each plot had four chambers for gas emissions measurement (15 cm diameter, 15 cm headspace, pushed 10 cm into the soil); two were placed in the furrows and two on the plant beds. The concentrations of N_2O in air sampled at 0 minutes and 60 minutes after sealing the chamber with a gas-tight lid were determined using a laboratory gas chromatograph. Hourly emission rates were calculated from the increase in N_2O concentration with time over the duration of chamber closure, then extrapolated to a daily flux result. Cumulative losses within each of the six sampling events were determined by linear extrapolation between sampling days. Days outside the sampling events were not included in the cumulative totals.

Plant measurements

Treatment effects on cotton crop production were evaluated by 3 × 1 m length biomass cuts per plot at peak biomass, 3 × 1 m length hand-picked lint samples at harvest, and machine harvesting by commercial cotton picker in the middle six rows of each plot over the entire plot length. Nitrogen concentration in dried and finely-ground plant and seed samples was measured by combustion analyser.

Results

Soil mineral N

Surface soil nitrate concentration was not different between the two treatments at any sampling time (data not shown). However, sampling location showed a much greater nitrate concentration in the side of the plant bed (hill) above the N fertiliser bands, regardless of its proximity to the irrigated furrow (Figure 1). The non-fertilised side of the hill tended to be higher in nitrate than either of the two furrows, indicating that some nitrated moved sideways within the plant bed. Concentrations declined between October and November as the crop established, but then increased again by the December sampling, most likely because this occurred shortly after the first water-run N application. Additional water-run N maintained the nitrate concentration in the non-fertilised side of the hill, but the concentration in the fertilised side of the hill continued to decline with time until February, when all locations tested low for the remainder of the season.

There were no significant effects from either N treatment or sample location on the mineral N at any depth to 90 cm when sampled soon after harvest (data not shown). There was an average of 34 kg N/ha remaining in the soil to 90 cm depth, with approximately half in the top 0–30 cm.

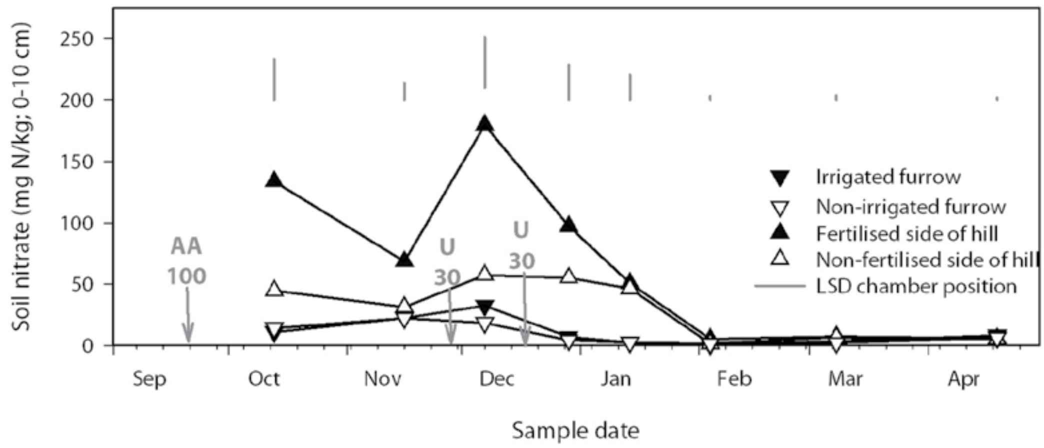

Figure 1. Surface soil (0–10 cm) nitrate concentration with time in the four sampling (chamber) locations in each plot. Results for T1 and T2 were not significantly different so are combined in this graph.

Nitrous oxide emissions

The chamber measurements showed a strong influence of location within the plot on N_2O emitted (Figure 2). The highest emissions occurred following the first irrigation event, especially from chambers located on the fertiliser band. Fluxes from the other positions were much lower and not significantly different. While there was no significant treatment difference on cumulative N_2O loss in the week following the first irrigation (Figure 3), there were differences in patterns of N_2O release (Figure 2), which were probably related to differences in the water content of the soil in the fertilised hill positions. In the fertilised hill side position of T1, fluxes on day one were high and increased on day two, and then declined. In the fertilised hill side position of T2, fluxes on day one were minimal, then increased to very high on day two and declined substantially by day four. The fluxes from the fertiliser band location had not reached the baseline emission level after seven days post-irrigation.

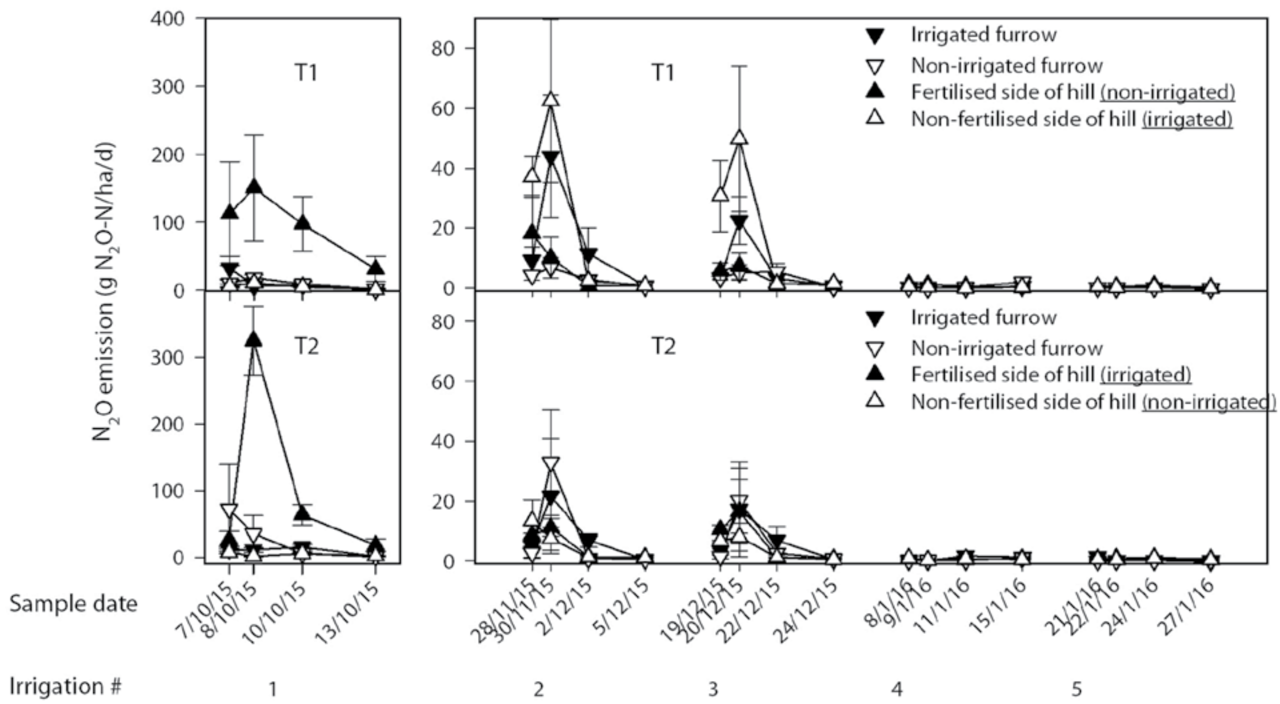

Figure 2. Daily nitrous oxide emissions from the Gunnedah experiment as influenced by N location treatment and chamber position.

Moderate N_2O emissions occurred in response to the water-run urea applied in irrigations two and three. Irrigation two was the only event when there was a significant treatment effect on N_2O loss, with more N_2O released from T1 than T2. The highest fluxes in T1 were found in the non-fertilised hill position (next to the irrigated furrow). By contrast, fluxes in T2 were not affected by chamber position. There were negligible N_2O emissions in response to irrigations four and five. Cumulative emissions across the five sampling occasions showed no significant difference between the treatments, but the fertilised band position was clearly the greatest overall source of N_2O emitted.

Plant results

There were no N location treatment effects on plant population, boll number, dry matter, plant N content, lint yield, lint quality or seed N content. Yield averaged 14.2 bales/ha across both treatments.

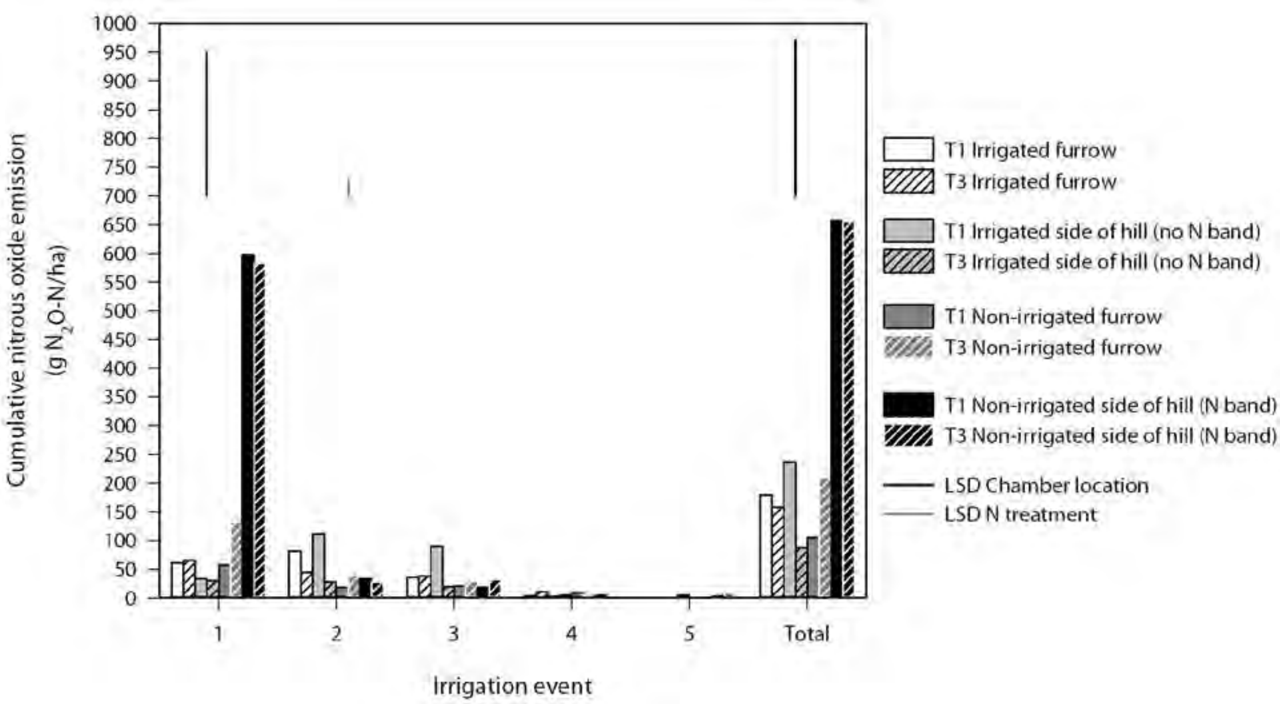

Figure 3. Cumulative N_2O emissions from the Gunnedah experiment as influenced by N location treatment and chamber position.

Conclusions

The soil mineral N results indicated that the majority of the pre-plant N fertiliser remained in the hill-side position where it was applied, with not much lateral movement evident. Irrigating the furrows beside the fertiliser band rather than those on the other side of the hill from the fertiliser band increased the initial intensity of N_2O released after the first irrigation. However, there was no net difference in N_2O emitted in total from that sampling campaign of emissions, nor across all the sampling events combined. Following the water-run urea applications, N_2O emissions were greater from the non-fertilised hill of T1 (next to the irrigation water) than in T2 (next to non-irrigated furrow), but were similar elsewhere. Overall, there was no net difference in total N_2O emitted between the two treatments when losses for the five key irrigation measurement periods were combined, and no effects on any agronomic parameters.

Therefore, there were no environmental or agronomic benefits to be gained by varying the location of the N fertiliser band in relation to the irrigated furrow.

Acknowledgements

This experiment was part of the project *Determining optimum nitrogen strategies for abatement of emissions for different irrigated cotton systems* (AOTG14013; 2013–17), with joint investment by NSW DPI and DAWR, and administered by CRDC.

Thanks to Rod Smith for providing the experimental site and applying the irrigation treatments in field. Thanks to Wayne McPherson for field assistance. All soil and plant N analyses were carried out by Clarence Mercer, NSW DPI, at the ISO9001-accredited laboratory at Tamworth Agricultural Institute, NSW DPI.

Does pre-plant nitrogen fertiliser location affect soil mineral nitrogen and nitrous oxide emissions from irrigated cotton at Moree?

Graeme Schwenke and Annabelle McPherson
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Key findings

- Changing the pre-plant nitrogen (N) fertiliser location from beside the non-irrigated furrow to beside the irrigated furrow increased nitrous oxide (N_2O) emissions, primarily from the fertiliser band location.
- Irrigating every single furrow instead of every second furrow did not significantly change N_2O emissions.
- Altering irrigation furrows in relation to pre-plant N fertiliser did not significantly affect mineral N in the surface soil, nor did it affect any measure of crop production.
- These results do not support changing from the current irrigation and N fertiliser placement system in use.

Introduction

In a typical cotton furrow irrigation system, water is applied to every second furrow. During the irrigation event, water 'subs' sideways through the plant bed from the irrigated furrow and eventually into the non-irrigated furrow. Pre-plant N fertiliser applications are often applied into the soil on the non-irrigated side of the formed plant bed usually to a depth below that of the furrow.

In this experiment, we compared this conventional practice with two alternative pre-plant N fertiliser placements in relation to the irrigated furrow, to investigate the potential impact on soil mineral N concentrations, nitrous oxide (N_2O) emissions, and cotton production.

Site details

Location	'Redbank' Moree
Co-operator	Ray Fox
Soil type	Black vertosol. The soil (0–30 cm) had 54% clay, 20% sand and 26% silt.
Rainfall and irrigation	At Moree, there was 5.2 mm of rainfall during the 38-day pre-plant period between N application and sowing, and a further 340 mm of rainfall during the cropping season. The crop was irrigated 11 times (including one pre-plant irrigation) with approximately 7.5 ML/ha applied in total.
Trial design	Randomised complete block design with three replications of three treatments. Each plot was eight rows (× 1 m) wide and 380 m long (paddock length).
Sowing date	The site was sown with Sicot 748B3F on 15 October 2015.
Harvest date	The trial was harvested with a commercial six-row picker on 8 April 2016. All cotton from each plot was baled separately and then weighed, ginned and quality-tested at a commercial gin.

Treatments

Three treatments were applied (Table 1). Pre-plant N fertiliser was applied on 8 September 2015. In-crop N applications totalling 160 kg N/ha were applied as water-run urea in irrigations 4, 6 and 8.

Table 1. Summary of trial treatments.

Treatment	Pre-Plant N (as anhydrous ammonia)	Location of pre-plant N application	Irrigation location
T1	180 kg N/ha	Non-irrigated side of the plant bed.	Water into every 2nd furrow
T2	180 kg N/ha	One side of the plant bed only.	Water into every furrow
T3	180 kg N/ha	Irrigated side of the plant bed.	Water into every 2nd furrow

Measurements

Soil moisture and mineral nitrogen measurements

Soil moisture content was measured at each gas sampling occasion using a hand-held theta-probe calibrated using volumetric soil moisture measurements at each site. Soil mineral N (ammonium and nitrate) was measured in surface soil (0–10 cm) samples collected near each N_2O chamber location at approximately monthly intervals during the experiment. After harvest, mineral N was also measured in soil cores taken to 90 cm depth (0–30, 30–60, 60–90 cm) at each chamber location. At each sampling time, soil was extracted with 1M KCl and analysed colorimetrically using a flow injection analyser.

Nitrous oxide measurements

Nitrous oxide emissions were measured during five separate seven-day campaigns with samples collected 1, 2, 4, and 7 days after irrigations 1, 2, 3, 5 and 6 (irrigation 1 = pre-plant). Measurements done in the previous year showed negligible N_2O emissions from late-season irrigations, so these were not monitored.

Each plot had four chambers for gas emissions measurement (15 cm diameter, 15 cm headspace, pushed 10 cm into the soil); two were placed in the furrows and two on the plant beds. The concentrations of N_2O in air sampled at 0 minutes and 60 minutes after sealing the chamber with a gas-tight lid were determined using a laboratory gas chromatograph. Hourly emission rates were calculated from the increase in N_2O concentration with time over the duration of chamber closure, then extrapolated to a daily flux result. Cumulative losses within each of the six sampling events were determined by linear extrapolation between sampling days. Days outside the sampling events were not included in the cumulative totals.

Unfortunately, all samples from the first irrigation event were lost in transit to the laboratory.

Plant measurements

Treatment effects on cotton crop production were evaluated by 3 × 1 m length biomass cuts per plot at peak biomass, 3 × 1 m length hand-picked lint samples at harvest, and machine harvesting by commercial cotton picker in the middle six rows of each plot over the entire plot length. Nitrogen concentration in dried and finely-ground plant and seed samples was measured by combustion analyser.

Results

Soil mineral nitrogen

Surface soil (0–10 cm) sampling during the season found that neither treatment nor sampling position affected the concentration of ammonium N (data not shown). There was also no significant N location treatment effect on soil nitrate at any sampling time.

There were some large differences in soil nitrate according to sampling position, with very high concentrations found in the hill positions in early December (Figure 1). During January, soil nitrate increased in both hill positions before declining to low levels in February. The increasing nitrate concentrations in the hills through the season suggest that nitrate moved upward and sideways from the pre-plant N locations and from the water-run N applications.

At the conclusion of the season, deep soil core sampling to 90 cm found a total of 31 kg N/ha across all treatments. Treatment three had more nitrate N in the 30–60 cm zone than the other two treatments, with most found in the fertilised hill and irrigated furrow (next to fertiliser band positions). In the 60–90 cm zone, nitrate concentration was higher under the fertilised furrow in all three treatments.

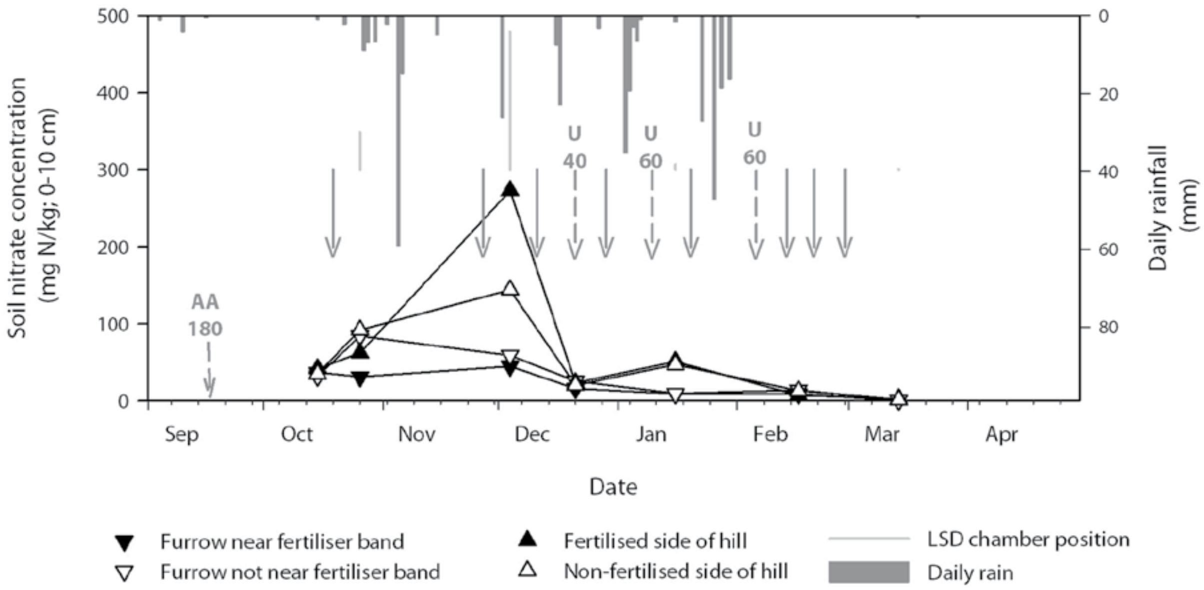

Figure 1. Surface soil (0–10 cm) mineral N at the Moree experiment as influenced by chamber location, and daily rainfall (mm, from top). AA = pre-plant anhydrous ammonia, solid arrows = irrigation with water only, dashed arrows = irrigation with water-run urea.

Nitrous oxide emissions

The N_2O emission results from irrigations 2, 3, 5 and 6 showed a variety of responses to different irrigation events and different treatments (Figure 2). There was generally little emission response to the second irrigation event in late November, despite there being large concentrations of nitrate in the soil at that time (Figure 1). Losses were greater from T3 than the other treatments, primarily due to a large flux from the fertilised side of the hill (next to the irrigated furrow). This position in T3 also had the highest N_2O losses in the following two measurement periods, and was highest when all results were combined. The third sampling event (irrigation 3) showed initially low emissions after the irrigation ceased, but then an increase after 30 mm of rainfall on day six of the week-long post-irrigation measurement campaign. There were no N location treatment differences in this campaign.

The fourth sampling event (after irrigation 5) produced very high N_2O fluxes for the first few days after the irrigation ceased, particularly in the fertilised hill position of T3. Total losses from T3 were significantly greater than T1 or T2. This irrigation event was water-only, but it closely followed irrigation 4 in which water-run urea had been applied. Emissions were lowest from the furrows not near the fertiliser band, especially in T1 and T3, even though this was the non-irrigated furrow in T3. In T2, all positions produced similar N_2O emissions.

Emissions of N_2O measured in mid-January after irrigation 6 were modest compared with the previous sampling, with most N_2O loss occurring within the first two days after the irrigation concluded. This is despite the irrigation occurring just five days after a 74 mm rainfall event at the site. As with the previous event, T3 showed the lowest emission from the non-irrigated furrow and highest from the fertilised hill position, while the highest emission from T1 was from the non-fertilised side of the hill (irrigated side).

When the results from these four sampling events were combined, N_2O losses from T3 were significantly greater than from the other two treatments, primarily because of the high emissions from the fertilised (irrigated) side of the hill.

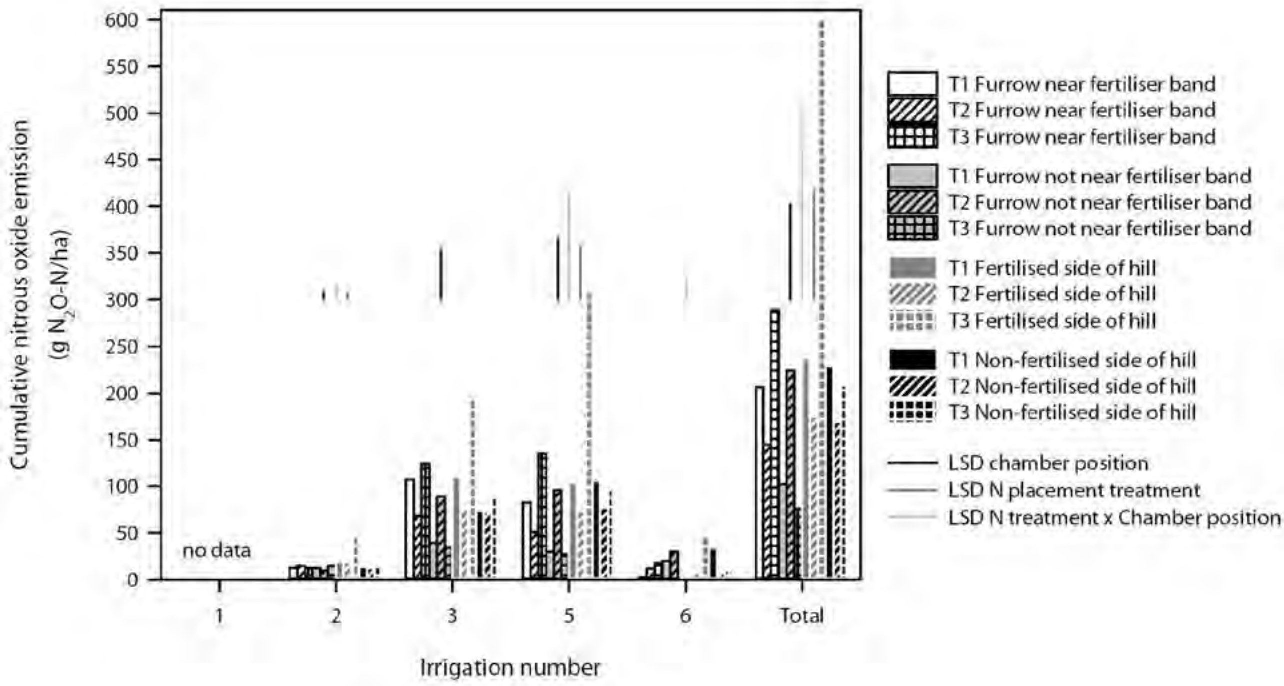

Figure 2. Cumulative nitrous oxide emissions from the Moree experiment as influenced by N location treatment and chamber location. Emissions were monitored for seven days following an irrigation event. There is no data from the first irrigation event.

Plant results

There was no impact from the N fertiliser location treatment on plant population, boll number, dry matter, dry matter N content, lint yield (either hand-picked or machine picked), lint N content or seed N content. Lint yield across the site averaged 13.2 bales/ha.

Conclusions

Even though we do not have data for the first irrigation, where N_2O losses are usually greatest, the data we do have is still instructive as to the potential impacts of changing irrigation strategy with respect to pre-plant fertiliser location. The experimental treatments examined here produced some clear indications that soil nitrate from pre-plant and water-run N applications can be highly mobile, both vertically within the soil profile and horizontally within the plant bed. The alternative system trialled in T3 appeared to increase N_2O emissions, compared with the current practice (T1), while the system with every furrow irrigated (T2) appeared to produce results no better or worse than T1.

None of the treatments trialled at Moree affected the cotton lint yield results. Changing the irrigation system to apply water into every furrow would require additional labour and materials for siphons. Altering the system so that the irrigated water is applied to the N-fertilised side of the beds appeared to increase N_2O losses. Therefore, there appears to be no environmental or agronomic benefit to changing the current irrigation setup in relation to pre-plant N placement (T1) to either of the tested alternatives (T2 or T3).

Acknowledgements

This experiment was part of the project *Determining optimum nitrogen strategies for abatement of emissions for different irrigated cotton systems* (AOTG14013; 2013–17), with joint investment by NSW DPI and DAWR, and administered by CRDC.

Thanks to Ray Fox for providing the experimental site and applying the irrigation treatments in the field and to Brooke Cutler and Wayne McPherson for carrying out the field sampling. All soil and plant N analyses were carried out by Clarence Mercer, NSW DPI at the ISO9001-accredited laboratory at Tamworth Agricultural Institute, NSW DPI.

Nitrous oxide emissions from irrigated cotton fields – variations in time and space

Graeme Schwenke and Annabelle McPherson
NSW DPI, Tamworth

Key findings

- Nitrous oxide (N_2O) emission into a closed chamber was found to be linear over our standard closure time of 60 minutes in three of the four chambers tested.
- Beginning N_2O sampling at 9:00–9:30 am appeared to underestimate the daily average N_2O flux, although there was no significant time effect in the higher emitting treatment. The sampling time was changed for the following season to start at 10:00–10:30 am.
- The average flux from the four manual chamber locations used in the main experiments (irrigated furrow, non-irrigated furrow, fertilised side of plant bed, non-fertilised side of plant bed) were found to give a good approximation of the N_2O flux averaged across 12 chambers covering all possible locations in a two metre cross section of the cotton field.
- These tests validated the assumptions made in devising the sampling strategy used in subsequent experiments.

Introduction

Measuring soil nitrous oxide (N_2O) emission involves pushing a chamber into the soil, sealing the chamber for a period of time, then sampling the air within the chamber headspace to measure the increase in N_2O concentration during the sealed period. The length of time that the chamber is sealed can affect the results; too short and low emission rates cannot be measured; too long and the N_2O could be so concentrated that it causes a feedback effect slowing the rate of N_2O emitted. If feedback occurs, then the pattern of emission becomes non-linear and a single end-of-chamber-sealed sample will not give an accurate measure of the N_2O flux. We typically use a 60 minute closure time.

Gas emissions are also known to vary with the time of day they are made, principally due to changes in the soil temperature affecting the rates of the soil processes contributing to the N_2O release. Previous research has often found that, when significant N_2O emissions are occurring, maximum fluxes are in the afternoon and minimum fluxes in the early morning – provided soil water content is constant. Manual chamber measurements are therefore typically made in the late morning when the flux rate should approximate the average rate for a whole 24-hour period.

In an irrigated cotton soil, conditions of soil water content and mineral nitrogen (N) content (from pre-plant and water-run fertiliser) vary tremendously, so the sampling chamber locations are important to get an accurate 'average' flux for the plot as a whole. Since every second furrow is irrigated, there is a two metre cross-section of different soil conditions that is repeated across the field. We typically use four manual chambers of 15 cm diameter with two in the furrows, and one on either side of the plant bed.

In 2015, we conducted three intensive gas sampling experiments to explore the assumptions used in our regular N_2O emissions sampling. These campaigns examined;

1. the variation in N_2O emissions in relation to chamber closure time
2. the variation in N_2O emissions over a full 24-hour period
3. the variation in N_2O across a two metre cross section of hills and furrows within a cotton crop.

Site details

Location	'Ruvigne', Gunnedah
Co-operator	Rod Smith
Soil type	Black vertosol (medium clay). Soil (0–30 cm) texture was 65% clay, 9% sand and 26% silt.

Nutrition and soils

Rainfall and irrigation	These investigations occurred in a single week following the second irrigation (water-run urea applied). There was no rainfall during this week.
Sowing date	The site was sown with Sicot 74BRF on 1 October 2015.
Harvesting date	The trial was picked on 8 May 2016.

Trial designs

1. **Chamber closure time**: N_2O concentrations in air samples were collected from four different chambers at 15-minute intervals for a total of 90 minutes.
2. **Time of day of measurement**: a semi-automated sampling system was used to measure N_2O flux in four different chambers (two chambers each in two treatments) every three hours over a 24-hour period. The samples were collected starting on the second day after the second irrigation. These chambers were 50 cm × 50 cm × 15 cm and were situated directly over the plant bed. On lid closure, air samples were collected at 0, 30 and 60 minutes. Treatment 1 (T1) had 30 kg N/ha applied as water-run urea during the irrigation, while T3 was irrigated with water only.
3. **Sampling location:** Immediately following the second irrigation, 12 manual chambers (15 cm diameter × 15 cm high) were situated in a two-metre-long transect perpendicular to plant rows. Air samples were collected from each chamber both before and 60 minutes after being sealed with an airtight lid. Daily N_2O flux was calculated by the rate of increase in N_2O concentration with closure time, averaged over 24 hours. Sampling occurred at 1, 2, 4 and 7 days after the irrigation event. We compared the average N_2O flux results gained using the usual four chamber positions against the average from the 12 chambers covering all possible hill and furrow positions. Soil water content was measured from each position at each gas sampling time. Surface soil (0–10 cm) mineral N was also measured from all 12 positions before the irrigation, and again after the gas sampling experiment concluded. This trial was unreplicated.

The site had 160 kg N/ha applied as anhydrous ammonia pre-plant to the non-irrigated side of the plant bed. These measurements were made in the week following the first of two in-crop applications of 30 kg N/ha applied as water-run urea in the second and third irrigations. The pre-plant N fertiliser was applied on 16 September 2015.

Results

Chamber closure time

Nitrous oxide emission rates varied greatly between the four chambers, but the increases in N_2O concentration with closure time were essentially linear for at least 60 minutes in three of the four chambers (Figure 1). The rate of N_2O concentration increase with time in these three chambers became non-linear for closure times greater than 60 minutes, so longer times are not advised when emissions are quite high, as at this sampling time. The other chamber in the four tested had a much lower flux, but also showed an unusual pattern of N_2O concentration with time. After an initial increase in N_2O concentration between 0 minutes and 30 minutes, the N_2O concentration then remained stable until 75 minutes, after which it also declined.

Time of day of measurement

There was significant N_2O emission activity from T1, but much less from T3 during the first few days after the second irrigation, as T1 was irrigated with water-run urea (Figure 2). There appears to be a trend in N_2O emissions that roughly follows soil temperature (albeit with a lag of several hours). However, while N_2O flux varied with time in T3, the apparent trend for T1 was not significant due to the large variation between replicate chamber results. The dotted lines in Figure 2 indicate the mean flux for each treatment. Compared with the average of the eight measurements over a 24-hour period, taking a single daily measurement at 9 am would have underestimated the daily average by 31%. This data is from one single day and might not represent the diurnal flux patterns occurring on other sampling days throughout the season.

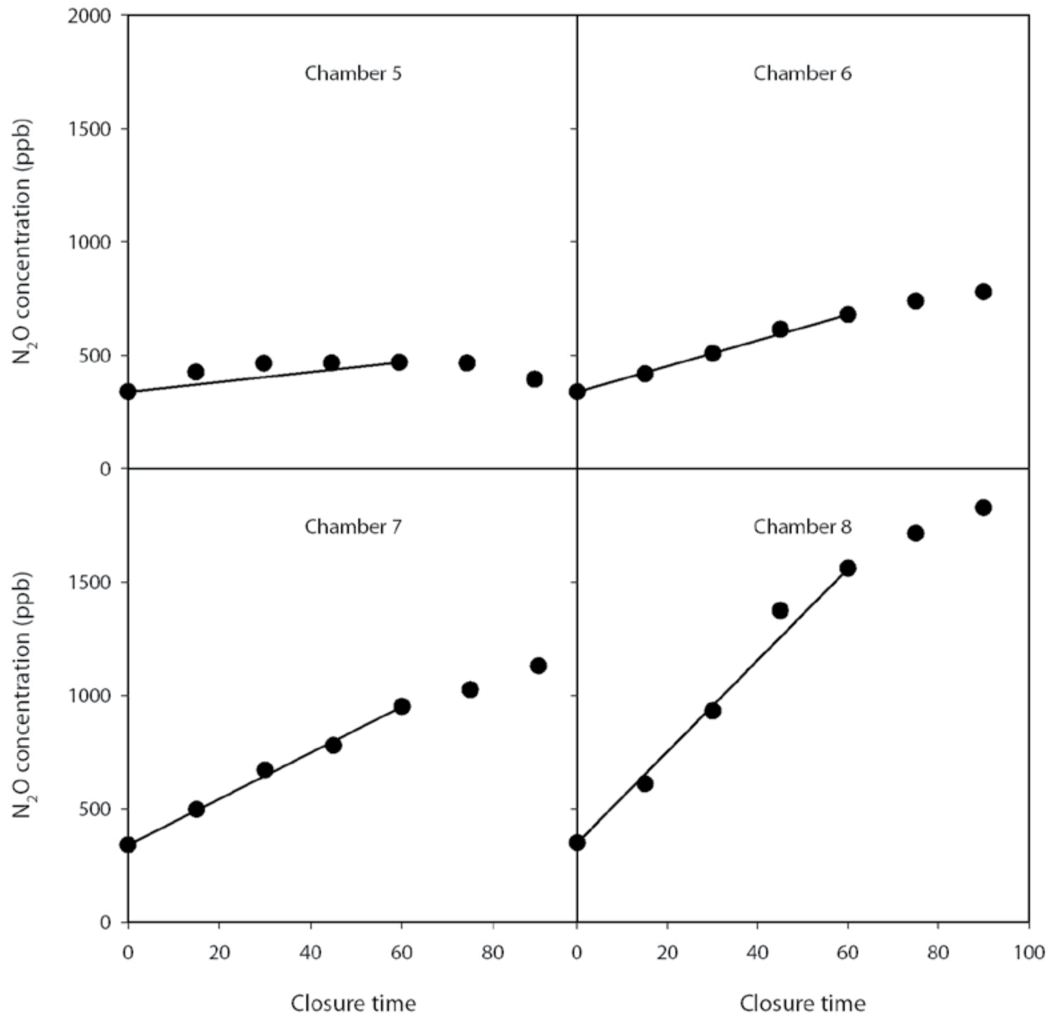

Figure 1. Change in N_2O concentration with chamber closure time in four individual chambers measured on the second day after the end of the second irrigation with water-run urea. Lines indicate the 0–60 minute linear relationship used to calculate fluxes for all other manual chamber measurements.

Chamber location

Before the irrigation event (day one), soil moisture content was very low in the surface and soil nitrate was unevenly concentrated in the top 10 cm of the soil, with high concentrations associated with/near the location of the pre-plant gaseous ammonia injections on either side of the non-irrigated furrow (Figure 3, top). After irrigation, the water content was initially high and even across all but the plant row positions, which were drier. Over the week-long experiment period, the moisture content stayed wetter in the mid-furrow positions.

The soil sampling done nine days after the irrigation showed significant changes in nitrate N distribution within the cross section, with increased nitrate concentrations associated with the pre-plant fertiliser bands, but also increased nitrate found on the sides of the irrigated furrow (from the water-run N). A large increase in soil nitrate under the first plant row is not easily explained and does not match the more modest increase under the second plant row position (Figure 3, middle).

Nitrous oxide fluxes in most positions increased in response to the changes in soil moisture and soil nitrate concentration caused by the irrigation event (Figure 3, bottom). One day after the irrigation concluded, N_2O flux was greatest on the sides of the irrigated furrow and also the hillsides adjoining the irrigated furrow. Fluxes in these areas increased further by day two. The sides of the non-irrigated furrow also showed increased emissions on day two. Conversely, on day four, emissions had subsided on the sides of the irrigated furrow, but increased in the irrigated furrow position. By day seven, all N_2O fluxes had returned to a low baseline (Figure 3, bottom).

The average flux from all 12 chambers on each day of measurement was approximately equal to the average of the four chambers normally used for the routine sampling. In terms of calculating cumulative N_2O emitted, there was little difference between four- and 12-chamber calculations, thus supporting our choice of the positions for the four chambers.

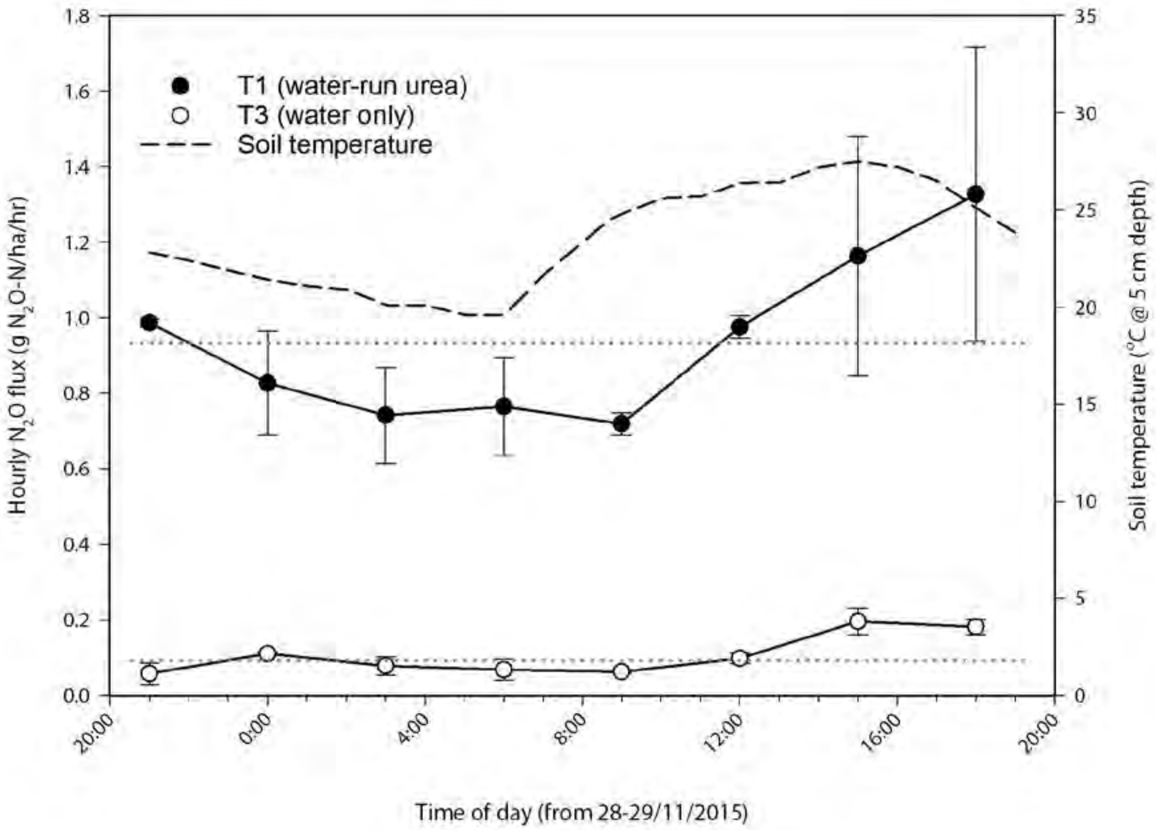

Figure 2. The influence of time-of-day of sampling on hourly N_2O flux on the second day following the second irrigation (with water-run urea in T1) – Gunnedah 2015. The dotted lines indicate the daily average of all measurement times for the two treatments. Soil temperature is shown as a dashed line in relation to right-hand axis.

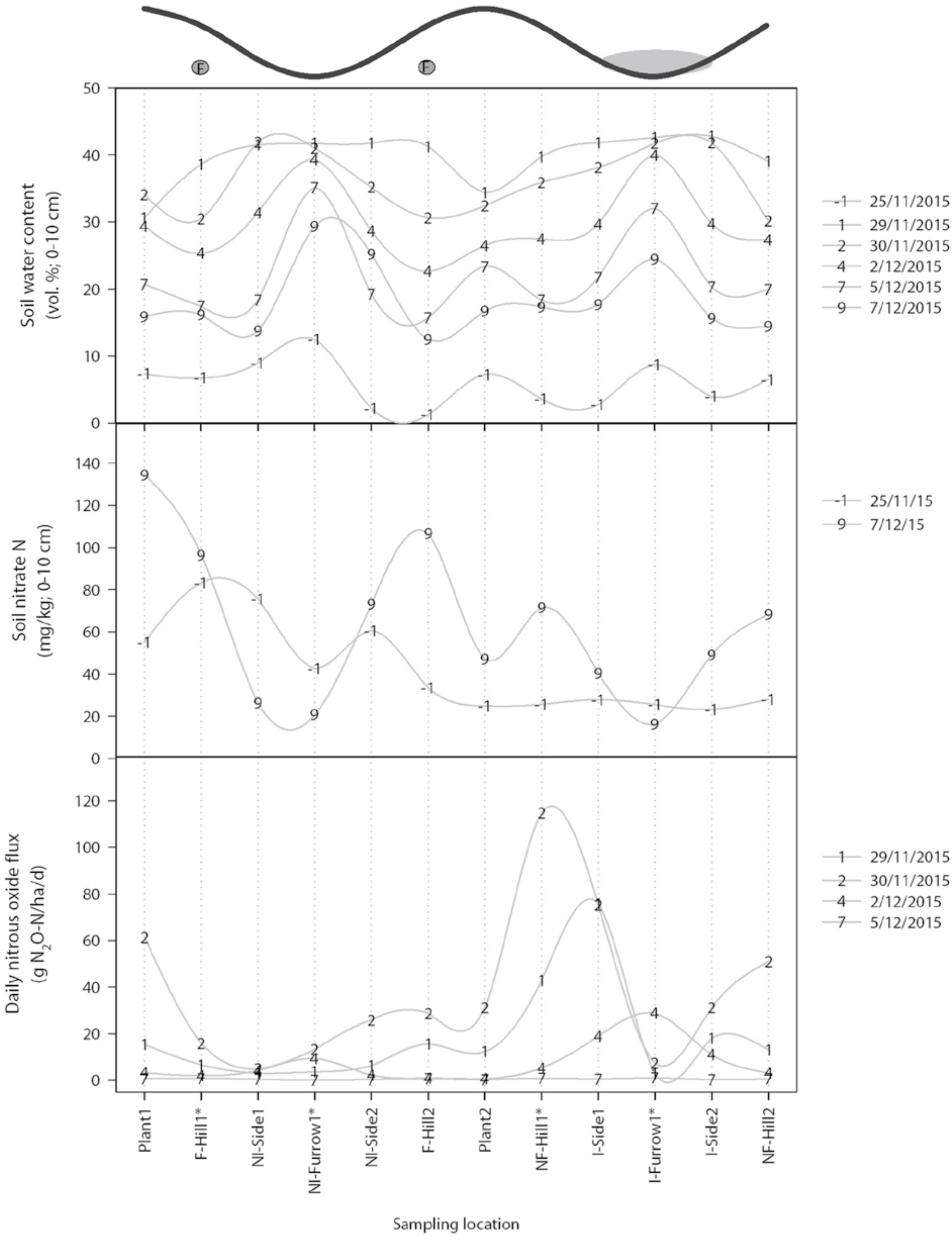

Figure 3. The influence of sampling position within the two metre wide cross-section on surface soil moisture [top], soil nitrate [middle], and daily nitrous oxide flux [bottom] following the second irrigation (with water-run urea) – Gunnedah 2015. Grey circles (above the graph) indicate the position of the pre-plant anhydrous ammonia. The shaded furrow indicates the irrigated furrow. Symbols on graphs indicate the number of days after irrigation. Positions named with * indicate the 4 typical chamber positions.

Conclusions

These three experiments were used to test some of the assumptions related to the techniques used in our regular N_2O sampling using manual chambers in irrigated cotton fields.

In the first test, we found that the assumption of a linear N_2O emission rate over the 60 minute chamber closure time that we commonly use was valid, so no changes were made to this part of the procedure. Shorter times would also have been valid for regular sampling, but shorter times also create time issues when large numbers of chambers are being sampled together across a large trial site.

In the second test, we found that N_2O flux as measured at our usual sampling time (starting 9:00–9:30 am) appeared to be underestimating the daily average amount, although the treatment with the higher N_2O flux rate (T1) showed no significant effect from time of day. Nevertheless, since the results suggested that sampling later in the morning would give a better approximation of the average daily N_2O flux, we modified our sampling in the following season to begin later (10:00–10:30 am).

The third test confirmed that our choice of four chamber locations within a two-metre-wide cross-section of the irrigated cotton field gave a good approximation of the N_2O emissions from the whole of plot area, so no changes were made to the routine procedure.

Acknowledgements

These experiments were part of the project *Determining optimum nitrogen strategies for abatement of emissions for different irrigated cotton systems* (AOTG14013; 2013–17), with joint investment by NSW DPI and DAWR, and administered by CRDC.

Thanks to Rod Smith for providing the experimental sites and for applying the N fertiliser treatments into the required plots. Thanks to Mandy Holland for assistance in field sampling. All soil and plant N analyses were carried out by Clarence Mercer, NSW DPI at the ISO9001-accredited laboratory at Tamworth Agricultural Institute, NSW DPI.

Maize nitrogen rate × hybrid responses – Gurley 2014–15

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Key findings

- The trial site suffered from very dry conditions for the first three months after sowing.
- As a result, final grain yields were very low, averaging 0.3 t/ha.
- There was no impact from varying nitrogen rate on any aspect of plant growth or grain yield at this site except for cob number per plant.
- Hybrid selection affected crop yield.

Introduction

Dryland maize remains a minor crop in north-western NSW. It is often considered a high risk dryland summer crop option in this environment, as favourable weather conditions (rainfall and mild temperatures) at flowering and grain fill are critical to achieving economically viable yields. Matching optimum nitrogen (N) nutrition to plant available water is essential to ensure that the maximum efficiency from inputs is achieved.

Nitrogen is the nutrient required in the largest quantities which, it has been suggested, accounts for around 20% of the variable costs associated with growing maize (Scott 2012).

This experiment compared plant characteristics and grain yield responses of three maize hybrids with varying rates of N applied at sowing or in-crop under dryland conditions at Gurley, south-east of Moree. An irrigated experiment was also conducted at Breeza on the Liverpool Plains in the 2014–15 season.

Site details

Location	'Bulgate', Gurley
Co-operator	Peter Newton
Soil nutrition	Soil characteristics presented in Table 1
Sowing date	17 September 2014
Fertiliser	42 kg/ha Granulock Z applied at sowing
Plant population	Target three plants/m^2 (30,000 plants/ha)
Rainfall	A total of 233 mm of in-crop rainfall was recorded at the experiment site (Table 2). The majority of this was received in December and January.
Temperature	Temperatures were recorded at the site using a tiny tag. The data presented in Figure 1, shows two peak times when temperatures were above 40 °C in late October and late November. This period of extreme temperatures coincided with dry conditions, which had a major detrimental impact on crop yield as this was the critical period before silking. There was also a high occurrence of temperatures above 30 °C during the overall crop cycle. The optimum temperature for fertilisation (pollen viability) is 28 °C for maize, and above 35 °C is considered lethal.
Harvest date	17 February 2015

Table 1. Soil chemical characteristics.

Characteristic	Depth (cm)				
	0–10	10–30	30–60	60–90	90–120
pH (1:5 $CaCl_2$)	7.70	7.90	7.90	7.50	5.10
Nitrate nitrogen (mg/kg)	13.00	11.00	8.00	3.00	3.00
Sulfur (mg/kg)	4.20	6.60	117.50	2228.00	3600.00
Phosphorus (Colwell) (mg/kg)	26.00	4.00	3.00	5.00	10.00
Organic carbon (OC) (%)	1.22	0.80	0.58	0.15	0.08

Table 2. In-crop rainfall at 'Bulgate', Gurley in 2014–15.

Month	September	October	November	December	January	February
Rainfall (mm)	10	0	16	71	121	16

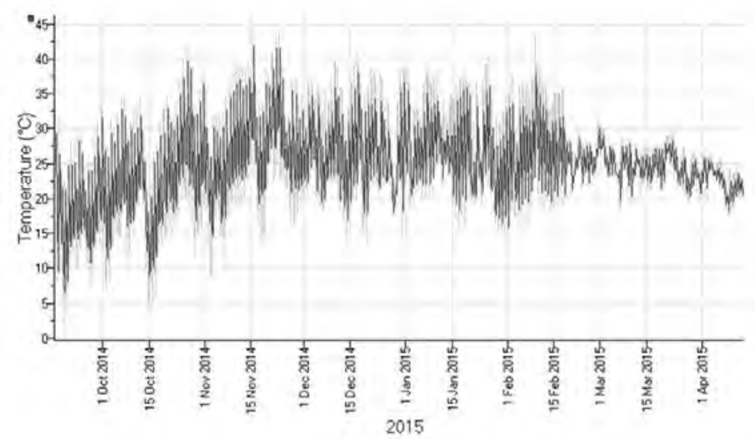

Figure 1. In-crop temperatures at "Bulgate", Gurley in 2014–15.

Treatments

Hybrids (3)

Pacific 624, Pioneer 1070, Pioneer 1467

Nitrogen rates (6)

Nitrogen applied at sowing as urea: 0, 50, 75, 100, 75:75 split and 150 kg/ha. The 75:75 split treatment had 75 kg/ha applied at sowing and 75 kg/ha surface spread at the 6–8 leaf growth stage.

Results

Establishment

Plant establishment was better than the targeted three plants/m^2 for all hybrids, ranging from 3.4–3.9 plants/m^2. Two hybrids, Pacific 624 and Pioneer 1467, established slightly higher plant populations than the remaining hybrid, Pioneer 1070 (data not shown).

Nitrogen rate had no effect on establishment (data not shown).

Tillering

The maize hybrids produced varying tiller numbers. The hybrid Pioneer 1467 produced more tillers per square metre and per plant than the other two hybrids (Table 3).

The N rate had no effect on tillers produced per square metre or tillers per plant.

Cob production

Both N rate and hybrids affected the number of cobs produced per square metre and per plant, but there was no interaction between the two factors (Table 3). The hybrid Pioneer 1070 produced more cobs per square metre than Pacific 624 and cobs per plant than Pacific 624 and

Pioneer 1467 (Table 3). Pioneer 1467 was not significantly different from the other two hybrids for cobs per square metre.

Nitrogen rate affected cob production, with the 100 kg/ha and 150 kg/ha rates producing the highest number of cobs/m^2; the 0, 50 and 75:75 kg/ha kg/ha split produced significantly fewer cobs (data not shown).

Grain yield

Grain yields were very low at this site in this season, on average 0.3 t/ha. There was no impact of N application on grain yield at this site. There was a significant impact of maize hybrid on grain yield (Table 3). The hybrid Pioneer 1070 was the highest yielding, followed by Pioneer 1467 which out yielded Pacific 624.

Table 3. Hybrid performance at 'Bulgate' Gurley in 2014–15.

Hybrid	Plants/m^2	Tillers/m^2	Tillers/plant	Cobs/m^2	Cobs/plant	Yield (t/ha)
Pacific 624	3.9	0.2	0.1	0.4	0.1	0.13
Pioneer 1070	3.4	0.0	0.0	1.5	0.5	0.48
Pioneer 1467	3.7	0.7	0.2	1.1	0.3	0.30
l.s.d.($P<0.05$)	0.33	0.21	0.05	0.43	0.13	0.08

Conclusions

At this very low yielding dryland experiment site, hybrid choice had the largest effect on all plant and yield characteristics. The effect from varying N rates was non-existent on all plant components except for cob production. The highest number of cobs per square metre was produced from the 75, 100 and 150 kg/ha treatments.

References

Scott JF (2012). Dryland maize (no till, feed). *North east budget series.* NSW DPI http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/175908/East-dryland-maize-12-13

Acknowledgements

This experiment was part of the project *Tactical crop agronomy of sorghum and maize in the northern region – NSW component* (DAN00195), with joint investment by NSW DPI and GRDC. The technical assistance provided by Delphi Ramsden, Peter Formann, Angus Hombsch and Nicole Carrigan (NSW DPI) is gratefully acknowledged. Thanks to Peter and Anne Newton, 'Bulgate', Gurley for hosting the experiment.

Maize nitrogen rate x hybrid responses – Gurley 2015–16

Loretta Serafin, Mark Hellyer and Peter Perfrement
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Key findings

- The starting soil nitrogen (N) at this site was 73 kg N, which was sufficient to supply the average crop yield of 2.1 t/ha, which was achieved.
- Consequently, there was no response to any of the nitrogen treatments applied.
- Hybrid selection had a major impact on plant structures, grain yield and quality. Pioneer 1467 produced more tillers than the other two hybrid maize varieties.
- Pacific 606 produced the highest grain yield at 2.65 t/ha and also had the highest 1000 grain weight and lowest screenings of the three hybrid maize varieties examined.

Introduction

Dryland maize remains a minor crop in north-western NSW. It is often considered a high risk dryland summer crop option in this environment, as favourable weather conditions (rainfall and mild temperatures) at flowering and grain fill are critical to achieving economically viable yields. Matching optimum nitrogen (N) nutrition to plant available water is essential to achieve the maximum efficiency from inputs.

Nitrogen is the nutrient required in the largest quantities and, it has been suggested, accounts for around 20% of the variable costs associated with growing maize (Scott 2012).

This experiment compared plant characteristics and grain yield responses of three maize hybrids to varying rates of N applied at sowing or in crop under dryland conditions at Gurley, south-east of Moree. An irrigated experiment was also conducted at Breeza on the Liverpool Plains in the 2015–16 season.

Site details

Location 'Kelvin', Gurley

Co-operator Scott Carrigan

Soil nutrition The site was selected for expected low starting soil N levels, however it was found to have 73.2 kg N/ha down to a depth of 1.2 m at sowing. The soil was a grey vertosol with a fairly neutral pH and generally low phosphorus levels (Table 1).

Table 1. Soil chemical characteristics.

Characteristic	Depth (cm)				
	0–10	10–30	30–60	60–90	90–120
pH (1:5 $CaCl_2$)	6.5	7.4	7.8	7.5	7.5
Nitrate nitrogen (mg/kg)	4	4	9	6	<1
Sulfur (mg/kg)	3.3	4.6	28.3	1630.8	320.2
Phosphorus (Colwell) (mg/kg)	8	3	<2	3	4
Organic carbon (OC) (%)	0.80	0.45	0.42	0.32	0.20

Starting soil water and rainfall The site was soil cored before sowing and found to have 149 mm of plant available water (PAW) to a depth of 1.2 m. Most of the PAW was in the 10–90 cm zone with a drier 90–120 cm soil layer below that. A total of 204 mm of in-crop rainfall was recorded at the trial site (Table 2).

Table 2. In-crop rainfall at 'Kelvin', Gurley in 2015–16.

Month	September	October	November	December	January
Rainfall (mm)	0	2	72.5	28	102

Sowing date	14 September 2015
Fertiliser	42 kg/ha Granulock Z applied to all plots at sowing.
Plant population & row spacing	Target 3.0 plants/m^2 (30,000 plants/ha) on 100 cm solid plant rows.
Harvest date	11 February 2016

Treatments

Hybrids (3)

Pacific 606; Pioneer 1414; Pioneer 1467

Nitrogen rates (6)

0, 50, 75,100, 75:75 split and 150 kg/ha of N applied at sowing as urea. The 75:75 split treatment had 75 kg/ha applied at sowing and 75 kg/ha surface spread at the 6–8 leaf growth stage.

Results

Establishment

Plant establishment was better than the targeted 3.0 plants/m^2 for all hybrids. Two hybrids, Pioneer 1414 and Pioneer 1467 established higher plant populations of 3.6 and 3.7 plants/m^2respectively than the remaining hybrid Pacific 606 which established close to the target at 3.1 plants/m^2.

Nitrogen treatments had no effect on establishment (data not shown).

Tiller production

The maize hybrids produced varying tiller numbers. Pioneer 1467 produced more tillers per square metre and per plant than the other two hybrids, which were not different from each other (Table 3). Nitrogen treatment had no effect on tiller production (data not shown).

Cob production

Nitrogen treatment had no effect on the number of cobs produced per square metre, but there was an effect from hybrid selection. Pioneer 1414 and Pioneer 1467 produced more cobs per square metre than Pacific 606 (Table 3). There was no difference though between the three maize hybrids for the number of cobs produced per plant; each produced on average 1.2 cobs/plant (data not shown).

Dry matter production

All treatments were sampled to measure the total amount of dry matter produced. On average, 6 t/ha was produced, however, there were no differences between hybrids or N treatments (data not shown).

Grain yield

Grain yield averaged 2.17 t/ha at this site in 2015–16. Nitrogen treatment had no effect on grain yield, but hybrid selection did (Table 3). Pacific 606 was the highest yielding hybrid at 2.65 t/ha, followed by Pioneer 1467, which produced a better yield than Pioneer 1414.

Grain quality

A sub sample was collected from each plot at harvest for quality testing. This data explains why Pacific 606 produced a higher yield with the same number of cobs per plant but lower cobs/m^2. The 1000-grain weight of Pacific 606 was significantly higher than the other two hybrids (Table 3) and it also had a higher kernel number when compared with Pioneer 1414, which was the lowest yielding hybrid in the experiment.

The level of screenings in Pacific 606 (0.6%) were also half those measured in the other two hybrids (1.2–1.3%).

Table 3. Maize hybrid performance at 'Kelvin', Gurley in 2015–16.

Hybrid	Plants/m²	Tillers/m²	Tillers/plant	Cobs/m²	Yield (t/ha)	1000 grain weight (g)	Kernel no (/m²)
Pacific 606	3.1	0.1	0.0	3.6	2.65	279.0	958
Pioneer 1414	3.6	0.3	0.1	4.4	1.78	233.2	762
Pioneer 1467	3.7	1.0	0.3	4.4	2.06	234.1	878
l.s.d (5%)	0.32	0.36	0.10	0.61	0.26	6.89	110

Conclusions

Grain yields at the site were average for dryland maize production in this region at 2.1 t/ha. Neither nitrogen rate nor application timing affected grain yield or any of the plant structures measured, including the amount of biomass (dry matter) produced. This result is explained by the starting soil nitrogen level of 73 kg of N/ha, which was sufficient to grow a maize crop of up to 2.65 t/ha in this experiment without additional nitrogen.

Varying maize hybrid choice had the greatest impact on all measurements at this site in this season. Pioneer 1467 produced the most tillers, but its cob production per plant was similar to the other two hybrids. Dry matter production did not vary with either hybrid or N treatments.

Pacific 606 was the highest yielding maize hybrid in the experiment. It produced the same number of cobs per plant as the other two hybrids, but the 1000-grain weight and grain size (screenings) were better.

References

Scott JF (2012). Dryland Maize (No till, Feed) – North East Budget series, NSW DPI website http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/175908/East-dryland-maize-12-13

Acknowledgements

This experiment was part of the project *Tactical crop agronomy of sorghum and maize in the northern region – NSW component* (DAN00195), with joint investment by NSW DPI and GRDC. Technical assistance provided by Delphi Ramsden, Angus Hombsch, Alice Bowler and Bronwyn Brennan (NSW DPI) is gratefully acknowledged. Thanks to Scott Carrigan, "Kelvin" Gurley for hosting the trial.

Deep banded phosphorus effect on chickpea root growth

Tim Weaver[1], Bruce Haigh[2], Stephen Harden[2], Graeme Schwenke[2], Peter Perfrement[2] and Peter Formann[2]

[1]formerly NSW DPI, now CSIRO, Narrabri; [2]NSW DPI, Tamworth

Key findings

- Deep phosphorus (P) placement at a depth of 20 cm resulted in root proliferation in desi chickpeas at Terry Hie Hie.
- Deep P applied in the plant line produced more vegetative biomass compared with deep P placed between alternate plant lines (66 cm spacing) four weeks after sowing.

Introduction

In northern New South Wales (NSW) and southern Queeland (Qld), long-term cropping on dryland farming systems has depleted P from the soil (Bell & Lester 2012). This has created a need to research nutrient replacement methodologies to improve fertility in the sub soil with the intention to increase yield (Dalal & Probert 1997; Bell et al. 2010; Bell & Lester 2012). Starter fertilisers are applied at sowing in most farming systems; however, secondary roots do not access the surface-applied P and thus may become nutrient limited. The role of P and its effect on roots at depth in cereal crops has been reported previously (Li etal. 2014), but not with respect to chickpeas. The aim of this research was to study root development under a chickpea crop and quantify root growth due to the addition of P at a depth of 20 cm.

Site details

Location	'Maneroo', Terry Hie Hie (150°05'37'E, 29°39'35"S)
Co-operator	David Anderson
Sowing date	4 July 2016
Variety	PBA HatTrick⁽ᴰ⁾
Plant population	Target 30 plants/m^2 with 33 cm row spacing.
Fertiliser treatments	0, 10, 20, 40, 80 kg/ha MAP (nitrogen (N) 10; P 21.9; potassium (K) 0; sulfur (S) 1.5) treatments placed 20 cm under the plant line, mid row (33 cm), and alternate row (66 cm).
Weed management	Post-sowing pre-emergent: Balance® 750 WG @ 100 g/ha and Simazine 1 L/ha on 4 July. In crop: two applications of Verdict™ at 100 ml/ha before flowering to control grass weeds.
Disease management	Targeting ascochyta blight: three applications of fungicides (Mancozeb) at1 kg/ha before rainfall events (July, August, September).
Harvest date	Due to waterlogging, the trial was not harvested.

Soil type and nutrition

Grey vertosol, pH$_{Ca}$ = 7.3 (0–150 cm)
Soil at this site is a self-mulching, grey vertosol (Figure 1a.) with an average cation exchange capacity (CEC) of 33.2 meq/100g. Soil is sodic below 0.9 m with an exchangeable sodium percentage (ESP) of 7.8%. P status down the soil profile before starting the experiment is displayed in Figure 1b and soil chemistry characteristics for the site are listed in Table 1. The plant available water content (PAWC) at sowing was 166 mm to 1.5 m. The Crop Lower Limit (CLL) and Drained upper limit (DUL) are shown in Figure 2.

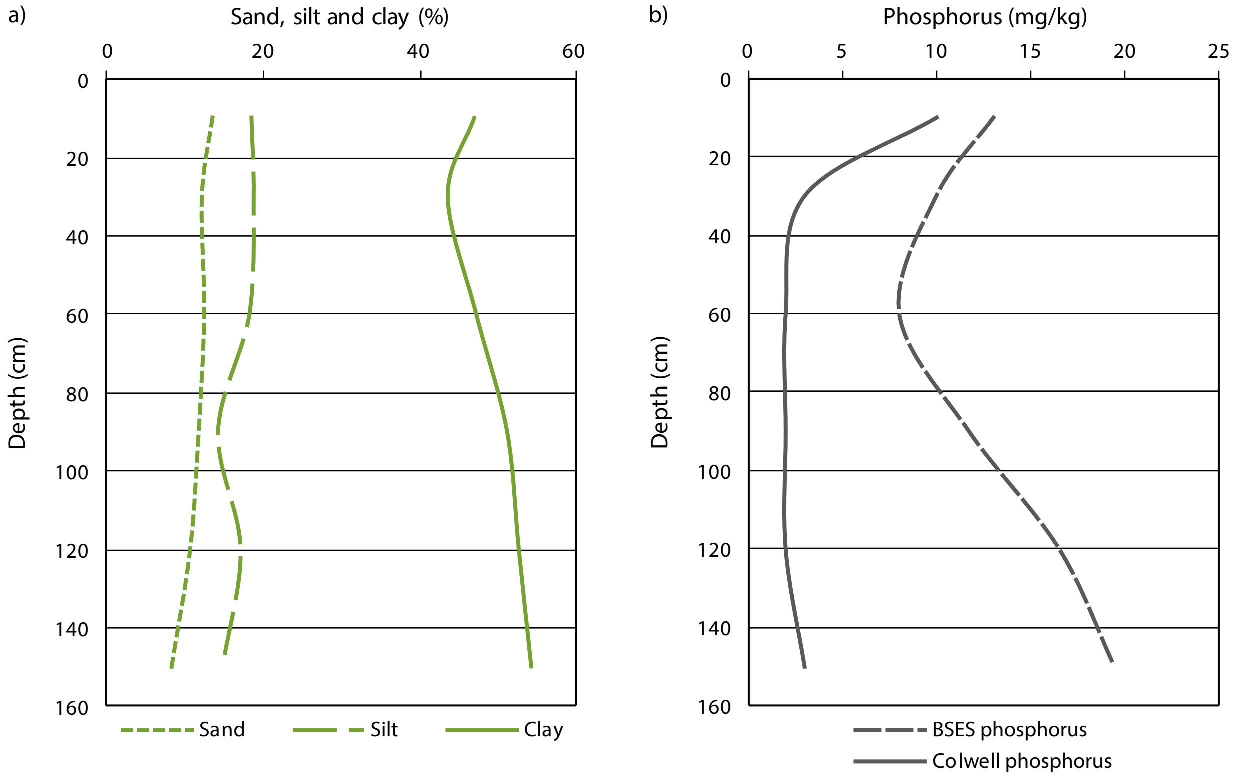

Figure 1. a) Soil particle size analysis (%); b) P content down the soil profile (mg/kg, Colwell and BSES) – Terry Hie Hie 2016.

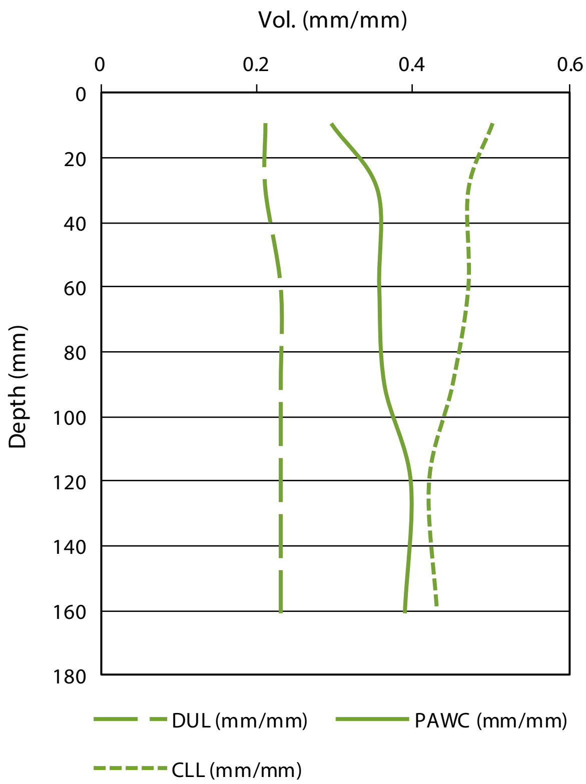

Figure 2. The plant available water content (PAWC) at sowing in July 2016 at Terry Hie Hie.

Table 1. Site soil chemical characteristics for 0–150 cm depth at Terry Hie Hie in 2016.

Characteristic	Soil depth (cm)					
	0–10	10–30	30–60	60–90	90–120	120–150
pH (1:5 $CaCl_2$)	6.2	7.2	7.4	7.7	7.7	7.5
Aluminium Exc. (meq/100 g)	0.10	0.09	0.10	0.09	0.10	0.06
Nitrate N (mg/kg)	14	9	8	6	6	6
Sulfur (mg/kg)	3.5	3.3	3.7	7.6	24.8	203.8
P (Colwell) (mg/kg)	10	3	<2	<2	<2	3
Organic Carbon (%)	0.78	0.50	0.48	0.33	0.22	0.25
CEC (meq)	29.34	33.23	32.85	34.00	34.84	34.91

Rainfall and temperature

There was a total of 384 mm of rainfall (Figure 3a) during the growing season and by November, the crop had succumbed to a combination of waterlogging and disease and was not harvested. The maximum and minimum temperatures during the growing season are shown in Figure 3b. Flower abortion was suspected due to the majority of the season experiencing night time temperatures below 15 °C up to November 2016. The maximum temperatures did not exceed 35 °C during the growing season (the maximum temperature when chickpea flowers are aborted).

Trial design

The experiment was a randomised complete block design.

Treatments

Product placement (3): Plant line, 33 cm (mid-row) and 66 cm (alternate)

Phosphorus rate (5): 0, 10, 20, 40 and 80 kg P/ha to a depth of 20 cm.

Reference treatment (4): farmer reference (no ripping tyne), control (ripping tyne no P) and 10 kg deep P/ha and 80 kg deep P/ha

Methods

The treatments were applied in January 2016.

Only the deep P bands at 33 cm spacing (mid row) to a depth of 20 cm were studied with the treatments applied on the 22 January at rates of 0, 10, 20, 40, 80 kg/ha. The crop was sown between the deep P bands at 33 cm spacing using Trimble® EZ-Pilot® with TMX-2050™ display for accurate placement and sowing.

A normalised difference in vegetation index (NDVI) reading (Trimble® Greenseeker®) was taken on the 16 August with the sensor height at 75 cm and crop height at approximately 10–15 cm. A BTC-2 minirhizotron video camera and an I-CAP image capture system (Bartz Technology Corp., Carpentaria, CA, USA) were used to capture root growth in August and November. Root tracing software, RootFly®, was used to quantify root growth in these images. Clear polycarbonate tubes were installed to a depth of one metre at 45° in the first three replicates under the three reference treatments.

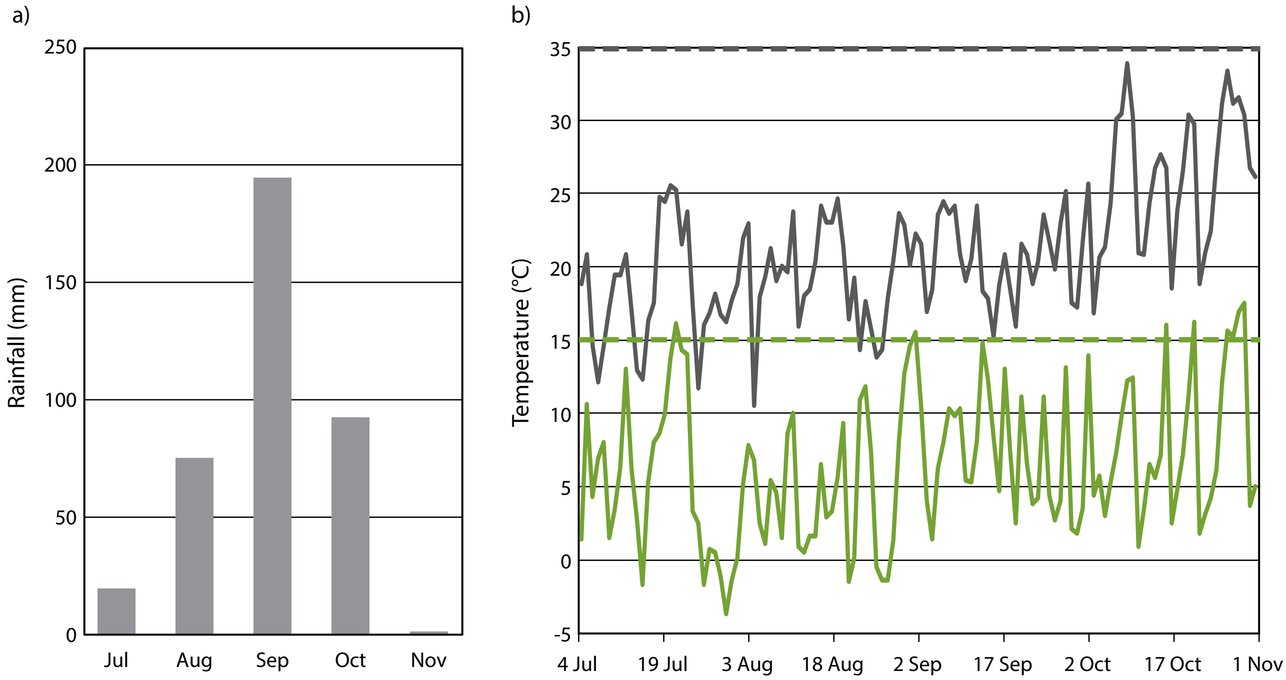

Figure 3. a) Growing season rainfall for 'Maneroo' in 2016; b) Maximum (—) and minimum (—) temperatures at Terry Hie Hie during the chickpea growing season. Note: Flower abortion occurs below 15 °C and above 35 °C.

Results

Root counts

Root counts were measured to a depth of 80 cm below the chickpea crop in the mid row banded treatment (Figure 4). The treatments used for these measurements were the reference treatments of; farmer reference, 0 kg P/ha, 10 kg P/ha and 80 kg P/ha. The root counts from the August (Figure 4a and 4b) and November (Figure 4c and 4d) measurements showed contrasting results. In August, the 80 kg/ha deep-banded P treatment revealed high root counts both in the surface and at depth under the plant line (Figure 4a). However, the root intensity changed from the plant line in August to the deep P band in November (Figure 4d); there were fewer root counts in the surface and more at depth (Figure 4d). Minirhizotron tubes were not installed in the plant line and alternate row treatments.

Crop biomass

An NDVI image was captured in August, approximately six weeks after sowing and shortly after the first minirhizotron measurements, to confirm if more roots translated to an increase in biomass. The NDVI data supported this relationship as shown in Figure 5. The NDVI index at V8 (eight nodes; four branches) indicated that the 80 kg/ha of deep P in the mid row was being accessed (Figure 5, $P<0.1$ *). Under the mid row, the chickpea roots were exploring 15 cm either side of the plant line and accessing the deep P band at 20 cm. The minirhizotron tubes were not installed in the plots where deep P was applied under the plant line or alternate rows.

Root length, diameter and volume

The root length, diameter and volume were higher under the 10 kg/ha and 80 kg/ha of deep P in the 33 cm mid row treatment compared with the farmer reference and control treatments (Figure 6 a–d).

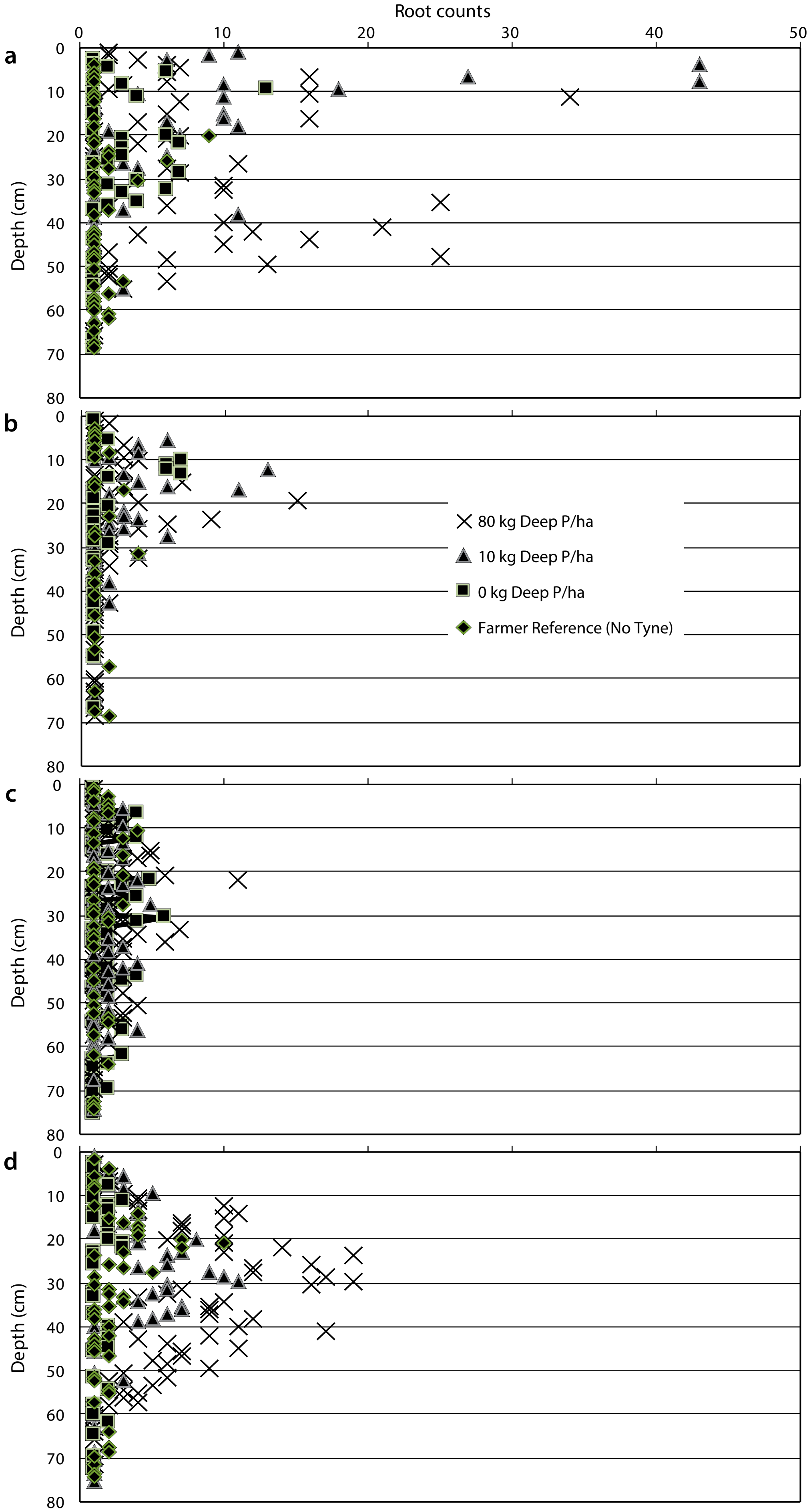

Figure 4. Root counts taken in August and November: a. Plant line (August); b. Mid row (August); c. Plant line (November); and d. Mid row (November).

Nutrition and soils

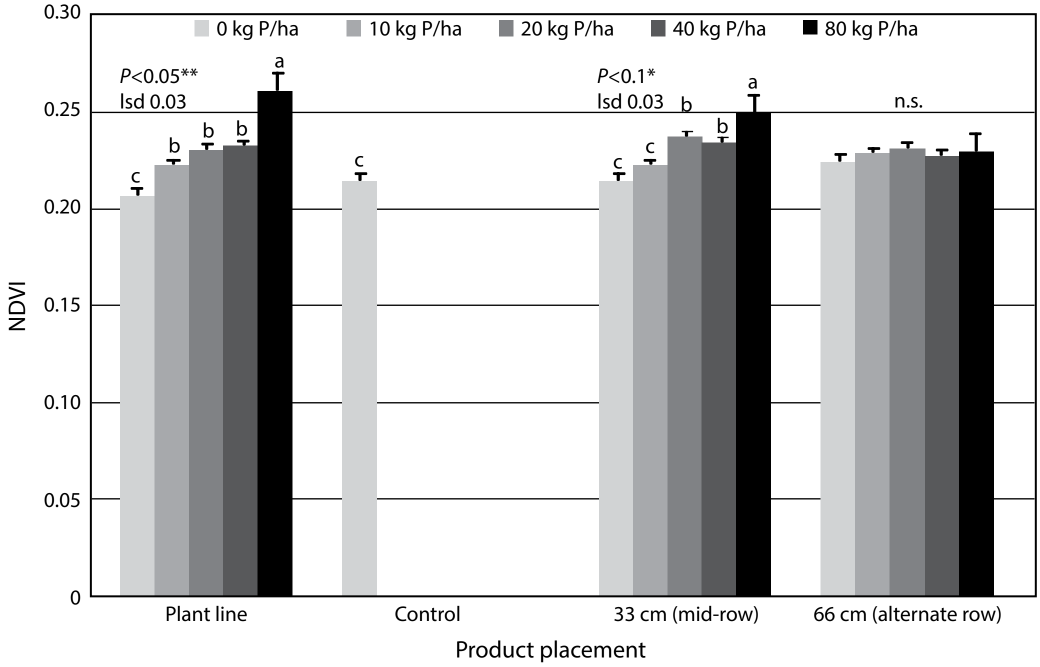

Figure 5. Normalised difference vegetative index (NDVI) of chickpea across the deep P site at Terry Hie Hie August 2016.

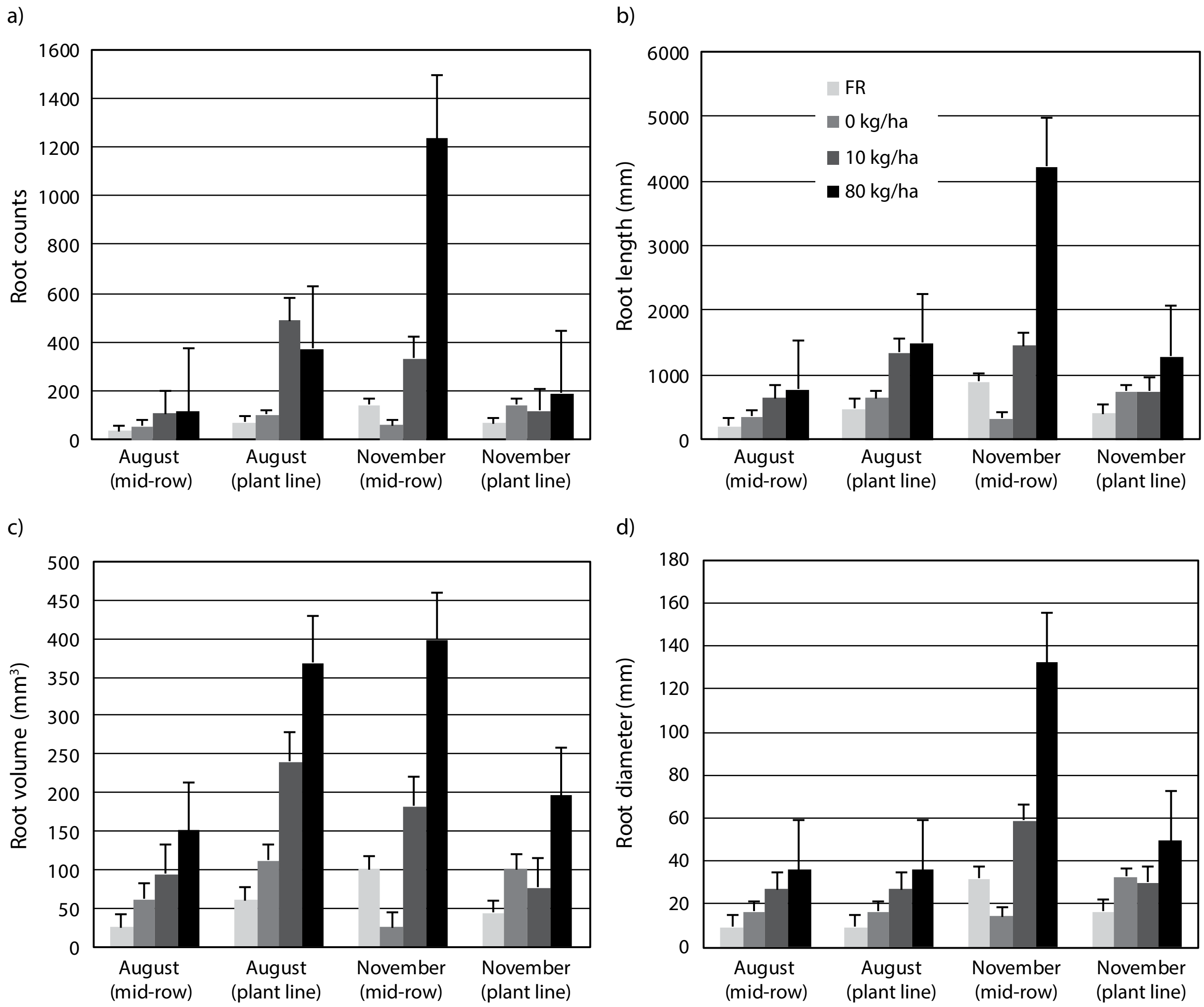

Figure 6. a) Number of roots to a depth of 80 cm; b) Root length; c) Volume; and d) Root diameter measured in August and November 2016 during the chickpea crop.
*Treatments were farmer reference (FR), 0 kg deep P/ha, 10 kg deep P/ha and 80 kg deep P/ha.

Conclusions

Placing P 20 cm into the soil was shown to stimulate root growth. Placing the deep P band between the plant line showed that initially root growth occurs at the surface, however, after the crop was waterlogged due to high rainfall in September and October, the root count reduced under the plant line and increased in and around the deep P band and below 20 cm. The root length and root volume also increased in the presence of deep P bands.

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